SOGERV Market Assessment

Peter Dauenhauer, Damien Frame, University of Strathclyde
Richard Kang'ombe, Sithembile Tembo, Mathais Zimba, Concern Universal

Contact: damien.frame@strath.ac.uk

V2 Nov 2016

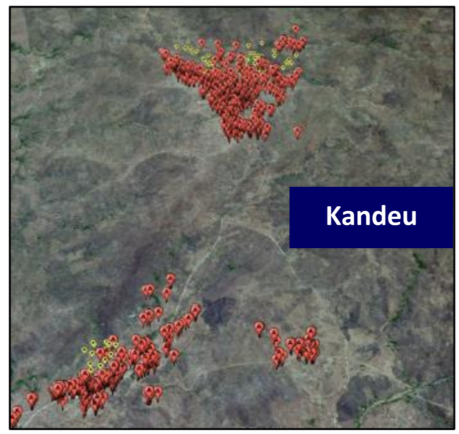
V1 April 2016

Overview

The Sustainable Off-grid Electrification of Rural Villages (SOGERV) Project seeks to create sustainable energy supply businesses in remote communities in Chikwawa District by deploying appropriate/affordable renewable energy technologies and applications. Little data is readily available in this context to guide the choice of technology and type and level of application. This study describes the market assessment approach taken to determine the viability of specific renewable energy technologies prior to implementation. The objective of the market assessment will provide a means for business planning and technology choice for those businesses.

Executive Summary

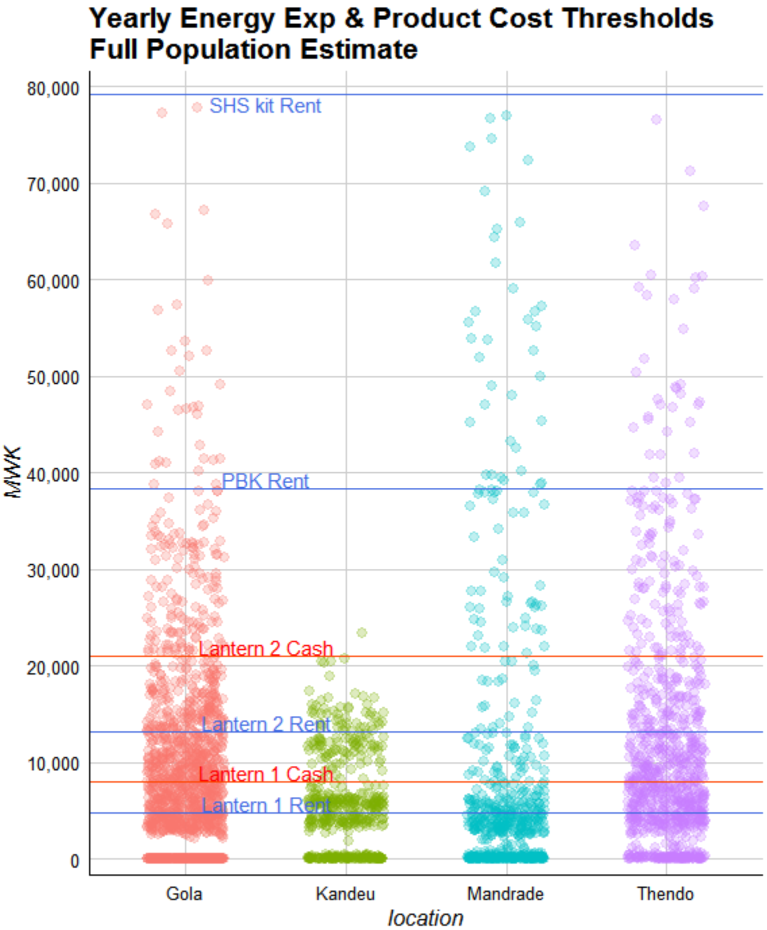
Market assessments for renewable energy are conducted for a variety of purposes; SOGERV's market assessment was designed to gain a better understanding of the current incomes, energy expenditures, and interest in particular productive businesses in four villages in Chikhwawa: Kandeu, Mandrade, Gola and Thendo. The results will be used to inform the design of the business, development steps for the project, and provide key inputs to the business model such as pricing and choice of products and payment arrangements which are most appropriate.



The SOGERV Market Assessment developed and tested new questionnaires for households and businesses to capture key data. Focus Group Discussion were held with a range of stakeholders in each village to verify the quantitative data and to explore issues which were difficult to capture in questionnaires. 314 household and 46 businesses were surveyed in total. This new data was supplemented with data from the SOGERV baseline and external sources to complete the analysis.

The target villages have very low incomes and equally low expenditure on energy. Interestingly, the link between energy expenditure and income was not consistent in each village; nor was the relationship statistically significant. Although modest, a market exists in both locations stemming from the willingness to pay by households, lack of competition, and stated interest in productive services. The entry cost for energy products and services is an important factor – at the critical threshold of around 6600 MWK per month of spend the number of customers in both villages reduces to zero. Thus, financing, which is in short supply and currently comes at a high premium (current averaging around 240% annual interest rates), must be packaged within any product/service offerings.

In Mandrade, the population is estimated at 3,037 in 604 households corresponding to an average household size of 5.03. In Kandeu, there are three nearby clusters of structures with a total population in this area is 2,143 in 473 households. This corresponds to an average household size of 4.53. Gola had an estimated 1334 households (6043 people) and Thendo had an estimated 841 households (3810 people).



The willingness to pay for specific objects ranging from solar lanterns to a mini-grid connection was explored. Respondents consistently undervalued the objects both in the willingness to pay for rental of the object or to buy it outright. The proliferation of low quality products and the 'craftiness' of vendors have led to skepticism from the consumers on the products that are currently available.

A new business established in these areas will need to overcome these negative legacies through good business fundamentals: fulfilling relationships with customers, demonstrated value, and sufficient training/marketing for customers. Inclusion of financial arrangements, through rental or leasing is needed to ensure that prices are sufficiently low for these consumers to get started. Current skill levels are low for potential local operators who could be involved in the project. It is likely that a significant training effort will be needed to support the skill shortage. In addition, a local supply chain for products and replacement parts will need to be established at all locations.

As shown in the figure for current energy expenses of households, even with the lowest pricing methodology and cheapest product, some households will not be able to afford any product. However, at all locations appear to be households and businesses that are interested and able to purchase renewable energy products to replace their current energy sources.

The Market Assessment revealed potential challenges that new businesses would face and equally some solutions. This included providing fair and published prices and taking steps to ensure theft does not become a problem. Risks of jealousy can be minimized by ensuring a transparent selection process for the local operator which enlists the support of the community. Finally, appropriate measures should be setup to avoid theft including: hiring security, locking up valuable equipment wherever possible or restricting access, and community policing.

Interest is high for the new energy supply business and the community is expecting general development benefits, which should be mostly achievable.

Figure – Business Opinion on likely profitability of various Productive Uses of Energy

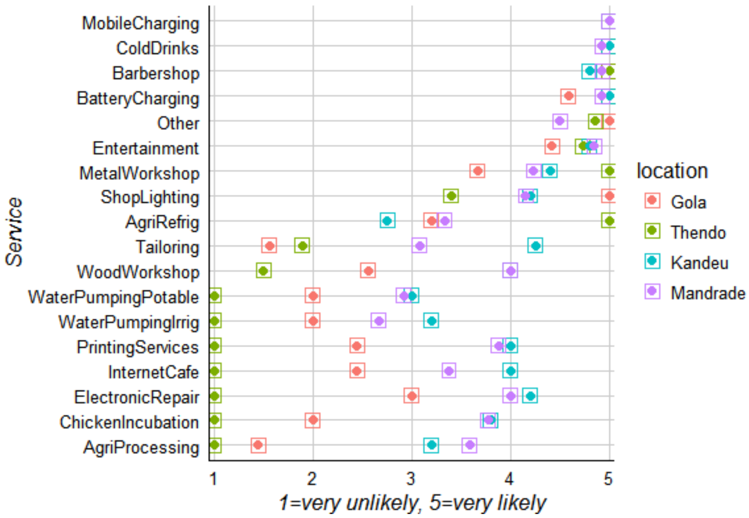
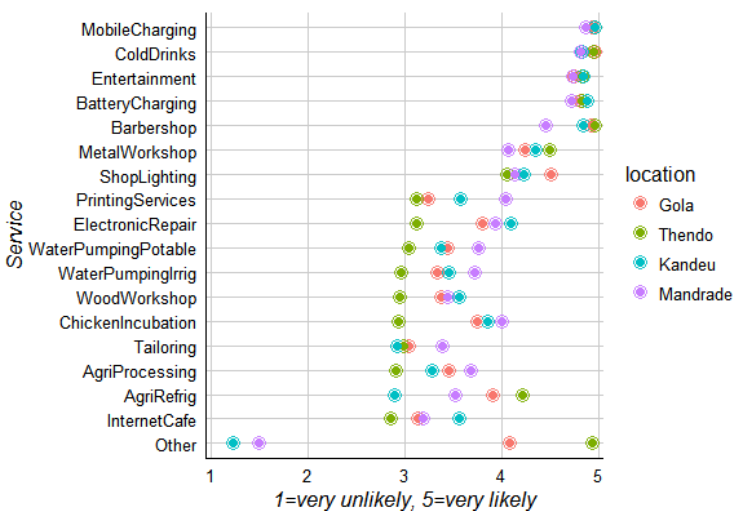


Figure – Household Opinion willingness to pay for various Productive Uses of Energy



Through the availability of well-priced products, households will benefit from basic lighting and mobile phone charging. Small businesses focusing on entertainment, mobile phone charging, and the sale of cold drinks are anticipated. Lighting at public facilities will improve the ability of teachers and health assistants to do their jobs more effectively.

In order for it to be sustainable, such provision needs to be economically sensible – or in other words, consumers need to be able and willing to pay for the products and services provided. Household demand for energy seems the most reliable with the data gathered assuming the entry price points low enough. Although businesses expressed their interest in products and setting up their own productive businesses, current energy spend is extremely low so they may need convincing of the value of energy access to the productivity of their business. The market assessment has revealed a relative agreement for households and business on the most desirable businesses which make productive use of energy.

The top seven include: **mobile phone charging, selling cold drinks, barbershop, charging batteries, metal workshops, providing shop lighting,** and **agricultural refrigeration**. This result provides a basis for further investigating the economic prospects of these activities and how best the village level energy provider can setup business-to-business energy services. It is recommended that business plans for these activities are developed alongside any technical modeling for electric systems.

Finally, the budgets for public facilities to pay for electric access appear to be limited, poorly defined, and may be subject to further negotiation involving district and community sources. Without a regular funding source to underpin the installed system, either the systems capability or expectations for sustainability will need to be scaled back. A subsidy approach may be possible at the village level, where productive activities priced on a commercial basis provide a subsidy for public facility funding, though the need to hike prices on the non-subsidized activities may push the poorer customers out of the market.

Specific ***Recommendations*** for the SOGERV Business made in the Market Assessment are:

- The **highest scoring productive uses** were mobile phone charging, battery charging, entertainment, barbershop, metal shop and shop lighting. The high scoring uses need to be passed on to the technical design team for consideration for standalone solar PV system design. Furthermore, the development of business plans for each of these activities is needed to ensure there is an economic basis for the investment.

- Using current business energy expenditures as the measure, they will not be able to pay for even the most basic products. However, the agreement between consumers and businesses in the productive services warrants continued exploration in providing **access to electricity for businesses as income source**. Furthermore, when asked about specific products, business appeared more willing to pay to gain access. This argument assumes that there is in fact a latent demand for electricity-enabled business products and services, but this has not been confirmed through the study.

- The low **Willingness to Pay (WTP)** for the available products would imply that a rental or leasing payment option should be pursued. Given the low familiarity with these arrangements, it necessitates the business model include training/marketing around how the financing arrangements are established.

- With the low levels of debt, ownership of bank accounts, and high interest rates, it is clear that **financial capacity in the villages are extremely limited**. The intended energy businesses established by SOGERV will therefore need to be able to manage a financing arrangement in order to make products/services affordable by the local population.

- For the business model design, **product selection should err towards smaller systems** which are less costly. Limited cash sales will be possible with the current availability of finance, to take on debt, in the villages. As a result, in order to provide access to more functional products, a financing arrangement will need to be offered by the installed business which allows either for a rent-to-own or fee-for-service. This will lower the income entry point for the products.

- **Available finance is extremely low and interest rates are eye-wateringly high**. According to the current debt-owners, the yearly interest rate well over 240% (in Gola it is over 500%), so any rate less than this could be considered acceptable. Average debt size was around 34,000 MWK. A more reasonable rate could be offered at the current Reserve Bank of Malawi rate set at 27%.

- For the current market, the cap on the yearly rental price appears to be very near the rental price threshold for solar home system, or 80,000MWK. **An "upper-income" segment could be set around 40,000 MWK/yr** rental with additional thresholds for products set at lower levels.

- Current **yearly energy expenditure** for lighting is assumed to represent the main market for the any new businesses as the current energy sources are supplanted with new renewables products. In <u>Kandeu</u> this is estimated to be 3.04 million MWK/year. In <u>Mandrade</u>, <u>Gola</u> and <u>Thendo</u>, yearly energy expenditure to 6.84m, 14.47m, 10.06m MWK/year, respectively.

- With the low level of competition, lack of existing renewable energy products, and WTP, products targeted at the right entry point should be in high demand. Emphasis on marketing of products (in some cases consumer training), and satisfying consumer relations will overcome current barriers and improve potential of the business to capture more of this market.

- The **required costs for institutional based PV systems** – totaling at around 6 million MWK/ year (see table), would likely require a large proportion of current budgets of the facilities, and are **most likely beyond what can immediately be committed by public facilities**. Further financial support will be needed to support the installations. SOGERV has identified a role in WASHTED to engage with the district on the options and financial obligations for installation of these systems. Failure of the district to provide basic funding may require system scale-back, or identification of a substitute income source, to remain sustainable.

System	Location	Monthly Cost	Yearly Cost	Costs for all systems
School -Classroom Block	K,M,T,G	38,000	456,000	1,824,000
School -Staff Room	K,M,T,G	38,000	456,000	1,824,000
Health Facility (small post)	K	38,000	456,000	456,000
Health Facility (small centre)	M,T*,G*	52,250	627,000	1,881,000
			total	5,985,000/year

- Ongoing financial support should be written into future district development plans which provided the mandate for paying for such services. Failure to do so will put additional pressure on the rest of the business (consumer- and business-energy supplies) to compensate for the lack of funding from public sources which may lead to sustainability challenges.

- As it appears that skills levels are minimal, personnel at any business will need significant technical training to competently manage the installed power systems**. A dedicated training provision is needed** and would ideally cover all the major aspects of solar PV systems installation, operation, maintenance, trouble shooting. If realistic levels of training cannot be provided, technical system design should be limited to a level appropriate to the operator. Furthermore, a district level training provision should be sought to reinforce a learning culture for when the project concludes.

- The lack of current stocks of renewables equipment is not unexpected, as a rural market no suppliers have set up shop in these locations. **Businesses setup up in these locations will require a supply chain setup for critical components**. Suppliers will need to be sought out in Chikhwawa Boma or Blantyre if necessary for the main components (Panels, batteries, charge controllers, inverters). In addition, a sufficiently sized inventory should be kept for consumer products sold in conjunction with the business and to minimize the impact of replacement on the consumer service provision.

- **Lack of consumer knowledge and the legacy of poor products** in the market translates to a likely consumer wariness to buy new renewable products, despite their quality. An energy supply business will need to combine consumer training with sales efforts so that consumers are informed. The onus is on the business to prove that its products and services are high quality. Measures such as providing a warranty and ensuring reliable service levels will reassure customers. SOGERV should provide general, community level training on renewable energy appreciate in order to dispel any misconceptions on solar products, use high quality Lighting Global certified products and ensure the economics for the household are clearly explained so they can recognize the savings and value they get from products.

Table of Contents

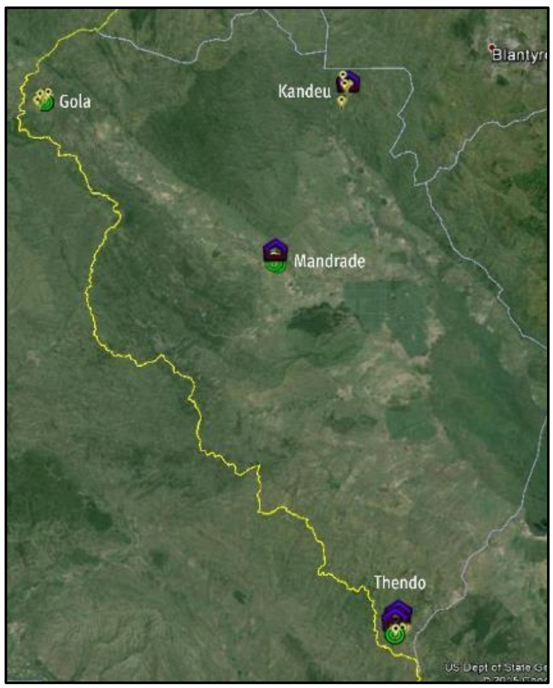
Contents

1 Introduction

1.1 Background

The Sustainable Off-Grid Electrification of Rural Villages (SOGERV) Project is funded by the Scottish Government and runs from 2015 – 2018. The project is led by the University of Strathclyde and partnered by Concern Universal – Malawi and WASHTED – Polytechnic. The project aims to deploy sustainable off-grid energy projects in Chikwawa district, Southern Malawi, that provide communities with affordable energy access.

Four locations were selected by the project to implement renewable energy projects: Kandeu, Gola, Thendo and Mandrade. These sites are labelled on the map of the Chikhwawa district in the figure.



During the first year of the project (April 2015 – March 2016) the main objectives are to prepare for the commissioning of the first two projects in April 2016 (Kandeu and Mandrade). The remaining projects are planned to begin operations in April 2017 (Gola and Thendo. This critical preparation period is aimed at establishing the SOGERV presence in the community and district, conducting a baseline survey, conducting a needs assessment, initial training with project beneficiaries, creating a business structure for each of the projects, and finally gathering sufficient technical information to determine procurement orders.

1.2 Market Assessment Strategy

Market assessments (MA) are critical for prospective renewable energy based businesses and can serve a variety of purposes. The scope of what is required within the MA depends on the scale, regional, national, sub-national, district, or even smaller. At the larger scale, the MA may emphasize macroeconomic indicators like income levels and interests rates along with high level resource assessments in order to make broad conclusions on various technologies. As the scope narrows to the consideration of data which is useful for a new small business, detailed information on the local market and specific questions may become more important.

This MA is of the latter category; the method is designed to provide specific insights into the local markets for the purpose of designing a sustainable business using solar energy. The areas of specific interest include:

- Expenditures and incomes for households and businesses in the market area
- Interest in specific 'productive uses' of electricity for households and businesses respectively.
    - For highest rated, creation of a techno-economic model to determine energy use requirements, system sizing requirements, and economic performance. A pricing structure will then be created for this.
- Existence of specific 'productive uses' already operating, and therefore an indication of competition
- 'Willingness to pay' (WTP) for specific energy products ranging from a simple solar lantern to a mini-grid connection
- Familiarity with payment arrangements including cash sales, fee-for-service, and rent-to-own and mapping of preference to specific energy products.
    - Economic models for each to determine pricing and pay back
    - Proportions of various energy products should be targeted to each location based on preference, willingness to pay, and underlying economic models
    - Estimation of financial performance of business
- Prevalence for mobile money
- Availability of finance and existing financial institutions
- Limited resource assessment for solar and capture diesel prices
- Cultural or social issues which may have an impact on the proposed business
- Public funding available for potential installations at primary schools and health centres at the specific villages
- Supply chain issues including skills and equipment

The SOGERV MA has implemented a field survey for households and business in each of the four target villages to inform the business model design. Following the data entry and cleaning, an analysis in each of the major areas is conducted to draw out recommendation for the project. The MA will conclude with specific recommendations for the proposed projects within SOGERV.

2 Literature Review of Market Assessments for Small Power Businesses in Developing Countries

There are a wide range of approaches taken to capture off-grid renewable energy market opportunities in developing countries. These are motivated by different objectives, for example: a comprehensive resource assessment and cost minimization for technology options, using income or wealth to estimate market size, analysis of infrastructure and supply issues, and perceptions on technology or even specific products among prospective clientele. This section discusses some of the prior market assessment studies in similar contexts in order to guide implementation of the SOGERV market assessment.

Bryne, Shen and Wallace [1998][1] conduct a feasibility study for a region in China's Inner Mongolia Autonomous Region which compares solar PV, hybrid (wind and PV), and gasoline gen-sets to determine the minimum cost technology choice. The study is aimed at household supply and compared technology sizing from a 60Wp PV system to a 300W/120Wp hybrid (wind, solar respectively). A model is developed which considers resource, economic and financial data, and technology configurations to produce an estimated energy output and economic valuation of specific energy applications. A levelized cost is produced for a specific set of technology configurations. Using the results of the resource modeling, a level of energy is determined per household for each technology set which can then be linked to hypothetical usage profiles. Household survey was completed on previously installed systems in the same area which verified duty cycles, energy use expectations, and actual LCOE of battery storage. The study found a hybrid PV-wind system (35-60Wp, 300W) to be the most economically preferred option for households with yearly energy consumption ranging between 400 – 750 kWh.

Howells et all [2002][2] develop a modelling and optimisation tool for a non-electrified rural village in South Africa based on data from surveys and electricity loggers. The model allows for a consideration of different technology configurations for full household energy end-usages; i.e. both electricity and non-electricity uses. Multiple technologies were considered including solar PV, grid electricity, wind generation, and diesel gen-sets. The overall objective was to minimize the cost of the supply technologies for the full village setting, where the authors simulated various scenarios for analysis. One interesting result from the simulation was that traditional fuels were not displaced by electricity-using alternatives in the case of cooking, space- and water-heating. In the case where grid electricity was restricted, the preferred technology switched to micro-hydro and then diesel gen-sets. Wind turbines and solar PV were not price competitive.

Kanase-Patil, Saini, and Sharma [2009][3] compare four modelled scenarios of renewables deployment against reliability and cost parameters for a cluster of 7 small villages in rural India. Given the lack of electricity access in the area of concern (5.27%) and remoteness from the main grid, the key question of the article centers around resource availability and its most cost effective utilization. Two software packages were used to compare cost of energy (COE): LINGO and HOMER. Scenarios which were considered include micro-hydro, biomass/biogas (for electricity production), solar, and wind energy. Incorporation of diesel gen-sets as an option into the decision set was specifically not included in the model as transport costs/requirements were considered too high for consideration. A limited sensitivity analysis was completed varying the biomass fuel cost. The final scenario which envisioned use of all technologies was determined to be the most reliable as well as cost effective.

---

[1] Byrne, J., Bo S., and Wallace, W.. "The economics of sustainable energy for rural development: a study of renewable energy in rural China." Energy policy 26.1 (1998): 45-54.
[2] Howells, M., Alfstad, T., Cross, N., Jeftha, L., & Goldstein, G. (2002). Rural energy modeling. Working Paper on Program on Energy And Sustainable Development, Center for Environmental Science and Policy, Stanford University
[3] Kanase-Patil, A. B., R. P. Saini, and M. P. Sharma. "Integrated renewable energy systems for off grid rural electrification of remote area." Renewable Energy 35.6 (2010): 1342-1349.

A study commissioned by GTZ [2009][4] evaluates, in particular, the market potentials for solar PV in the Kenya. The approach compares incomes for different sectors and current access level (on-/off-grid). The opportunity is determined quite simplistically by presenting stylized facts about the current level of industry and support its future growth. Different categories of technology implementation (such as solar home systems, off-grid schools, etc.) are reported with current penetration and full market sizes. In general, report does not offer any discernable methodology, instead using what has to be assumed as expert opinion on the various opportunities and obstacles for each sub-market. Analysis of the opportunity for solar PV hybrid systems and telecoms is an exception. Here, the authors estimated around 2000 off-grid base transmission stations where the majority could potentially be served through a hybrid system requiring 3kWp on each system. No costing or income estimation is made for this opportunity.

A comprehensive study [2012][5] is aimed determining the feasibility of the provision of village-level energy services in India, Tanzania and Ghana for later implementation. The study found solar PV and biomass-based technologies as the key options for these countries but cited various non-technical challenges such as institutional capacity and social context as critical for success. The authors use case studies and expert interviews from these countries to explore the implementation options and challenges for their implementation. While useful for understanding the wide ranging issues, specific business cases for the applications or technologies are never developed.

Determining willingness or ability to pay for electricity services is continual challenge in the sector. However, for business planning purposes, evidence to support financial projections and practical considerations such as where to set prices is a necessity. Although it considers willingness to pay for *improved* electricity services not, *new* services, a study by Abdullah and Mariel [2009][6] captures the issues around the methodology through an experiment held in Kenya. The model utilizes a multinomial logit model to estimate factors associated with different service choices such as pricing levels, type of provider (private, consumer), a set number of planned blackouts, and duration of blackout. The 202 respondents were comparing against the current Kenya Power and Light KPLC Service.

A survey [2014][7] conducted at a wind and solar hybrid micro-grid and charging station in Kenya capturing current energy use and expenditure of the local market. The results were intended to inform the business model design, namely the price point of the products and services offered. The survey results were corroborated with a focus group discussion (FGD) in which groups of 5-6 respondents were asked determine a best price point for the service. As the price point between FGD (higher) and survey (lower) differed, the implementers decided to use a middle point for the final price determination. In a follow up in 2015[8], despite the pre-installation field work, the business owner had found it challenging

---

[4] Hankins, M., Saini, A., and Kirai, P. "Target Market Analysis Kenya's Solar Energy Market". Berlin: GTZ (2009). 6-13.

[5] Bailey, Meghan, et al. "Providing village-level energy services in developing countries." Malaysian Commonwealth Studies Centre. October (2012).

[6] Abdullah, S., and Mariel, P. "Choice experiment on the willingness to pay to improve electricity services". Bath Economics Research Papers. No. 15/09. June (2009).

[7] Van Acker, Vincent, et al. "Survey of energy use and costs in rural Kenya for community microgrid business model development." Global Humanitarian Technology Conference (GHTC), 2014 IEEE. IEEE, 2014.

[8] Author documentation. Unpublished. (2014)

to fully rent out the inventory at the chosen price point. This highlights the room for error in estimation of the willingness to pay for such through these methods, even when combined.

In India, a survey was carried out in [2011][9] to determine factors associated with awareness and willingness to pay for solar home systems. One objective was to inform solar entrepreneurs of potential customers for their products. Factors which were estimated to be associated with higher willingness to pay included level of education, monthly household expenditure, and existing electricity access if the household had a relatively higher income. The approach asked respondents for their willingness to pay for a hypothetical 40-watt system, a price point the respondents would pay as well as similar values for leasing the system rather than buying. The researchers found a gap between willingness to pay and the estimated actual cost of the products of USD 120 to USD 208, respectively with the average gap being USD 52.56. Yearly payments respondents were willing to pay to lease the systems was much less than the required amount; averaging USD 29. Another study from India [2011][10] determined that non-income factors for adoption of solar home systems include high kerosene consumption and large number of household mobile phones. Adoption of relatively larger systems was associated with kerosene consumption levels due to the opportunity to replace these costs and larger number of children in the household

The study in Malawi in 2010[11] as part of the Millennium Villages Project described the introduction of solar powered lanterns in in poor rural areas using a market based approach. Three types of lanterns were trailed in the Zomba district. The products were sold as a cash sale or optionally in an installment plan and were sold through sales network consisting of a cooperative, handling bulk purchase, vendors, and customers. The product price buildup included a 25% shipping cost, 10% markup on cash sales or 20% markup on installment plans for vendors, and three options for customers: cash sale (10% markup on vendor price), installment plan (20% markup), and rental plan (30% markup). A selection process for vendors included capacity and willingness to sell the lanterns, stability in their existing business, and good standing among the community. Initial lantern sales numbered 54 with a price of USD 29.78 and USD 32.61 for cash sale and installment plan pricing. A survey which followed the initial sales confirmed significant reduction of kerosene and candles by a month following the purchase as well as an average household savings of $17.28 over the course of a year. Both vendors and households preferred cash purchases by a wide margin. The study recorded over 500 lanterns sold by vendors by end of the monitoring period. Cash sales remained preferred as demand outstripped supply and vendor tried to avoid the minor issues with repayments of the installment plans. The study authors questioned whether the long term sustainability of the model (cooperative and vendor) in the medium and long term once the local market was saturated.

[9] Urpelainen, Johannes, and Semee Yoon. "Solar home systems for rural India: Survey evidence on awareness and willingness to pay from Uttar Pradesh." Energy for Sustainable Development 24 (2015): 70-78.
[10] Komatsu, Satoru, et al. "Nonincome factors behind the purchase decisions of solar home systems in rural Bangladesh." Energy for Sustainable Development 15.3 (2011): 284-292.
[11] Edwin Adkins, Sandy Eapen, Flora Kaluwile, Gautam Nair, Vijay Modi, Off-grid energy services for the poor: Introducing LED lighting in the Millennium Villages Project in Malawi, Energy Policy, Volume 38, Issue 2, February 2010, Pages 1087-1097, ISSN 0301-4215, http://dx.doi.org/10.1016/j.enpol.2009.10.061.

3 Approach

3.1 Overview

Objective	Approach	Data Gathering Method
Estimate current and near future market for renewable energy services in village including power use requirements	Current energy use is captured through the SOGERV baseline energy use survey. This is extrapolated for the total number of households within 1 km of the village centre to estimate current market energy use as well as expenses paid. Substitute goods/services (such as lighting) that replace current expenses represent the minimum market. Additional 'aspirational' goods and services within households can increase the size of this market. This is determined within the *ability and willingness to pay* section. Near future market is based on energy use growth and greater local market capitalization.	Desk
Identify particular 'productive' businesses	This seeks to identify specific productive uses for businesses which may be an opportunity. The results of 3 complementary data gathering effort will be compared: • Focus Group Discussion with community stakeholders aimed at determining the existence of productive businesses and prioritization of options • Surveying local businesses to determine interest, willingness, and ability to expand into new markets • Surveying local households to determine prioritization of potential new businesses Productive uses which will be included are: – Battery charging – Tailoring - Electric sewing machines, dressmaking – Cold drinks refrigeration (coke, beer) – Agricultural Refrigeration (Fish, meat, milk) – Entertainment – TV and Music – Mobile phone charging – Barbershop – Water pumping for irrigation – Water pumping for potable water – Chicken incubation – Internet café and IT services	HH survey Business survey, Focus group discussion (FGD)

	– Printing services (photo printing, photocopying, document printing) – Wood workshop (Carpentry, furniture making) – Metal Workshop (grinding, drilling, welding, locksmith, blacksmith) – Shop lighting – Electronic Repair – Electric Fencing – Aeration for Aquaculture – Other	
Conduct a solar resource assessment	Renewable resources will be researched for each location using available online datasets and reports.	Desk
Determine "willingness" and "ability" to pay (for new energy services)	Questions will incorporated into the business and household surveys which attempt to determine ability to pay for various energy products and services. Several options from solar lanterns to a mini-grid connection will be considered. A visual aid (either the actual products or a printed paper) will be used to help the user understand the services that would be offered.	HH Business
Analysis of competition	This section seeks to identify any competition which currently exists for the productive uses and whether this is considered to meet the market needs. Competition will be determined through the FGD.	FGD
Transport/logistical/supply chain constraints	Types of constraints which will be determined include the availability of key energy system components and local technician skills to carry out installation and maintenance of equipment.	FGD
Create an accounting (economic/energy) for applications targeting specific applications	The purpose of this section is to determine the energy and economic considerations of implementing specifically identified electricity-using applications for consideration in business, following the results of the productive uses section. The highest prioritized applications will be researched in more detail to determine required capital outlay, availability of products, energy use of those products, size of energy system needed to support it, and any other considerations which are critical to implement it (for example, availability of other inputs) which may be required.	Completed in the technical design and business modeling (not in the Market Assessment)

	In the first stage domestic suppliers will be contacted to provide the energy and economic information for viable products. In the second stage, research on international suppliers will be conducted and they will be contacted to provide the same information.	
Analysis of potential social and cultural issues with technology and proposed business model	Perceptions on the use of renewables was previously captured within the baseline survey for both households and businesses. The results will now be presented to the FGD who will be asked to explore the reasons behind these perceptions. The FGD investigate perceptions on specific products (Pico-solar-products, solar-home systems, low-cost torches, and grid-power) to determine whether quality is perceived as an issue, understand expectations on level of use, and determine comfort level with the products. Finally, the proposed business model will be presented. The FGD will investigate the potential social challenges, issues, and benefits which may arise from this model.	FGD
Classify market segments and mapping to particular products/services	In the HH survey, income, expenditure, current energy use/expenses will be captured alongside the pricing for specific energy services which could be offered. The full market will be extrapolated using the sample data provided. For analysis it will be separated energy expenditure categories set by the cost of specific products – both rental and cash sale prices.	HH Survey
Availability of local finance for consumers, and finance for RE businesses	Households and businesses will be asked about current financial mechanisms used and available.	HH Survey Business Survey FGD
Prevalence of mobile money	Prevalence of mobile money and perceptions around it use will be captured in both surveys	HH Survey Business Survey
Preference towards payment arrangements (fee-for-service, rent-to-own, cash sales)	Prevalence around type of financing arrangements for energy services will be captured in both surveys. Reasons behind these preferences will be investigated in the FGD	HH Survey Business Survey
Public funding capabilities for any potential public service provision (i.e. at schools / heath facilities)	Current budgets at schools and health centres for energy services will be captured. Any additional budgets such as maintenance will also be captured and disaggregated into typical uses.	Institutional/ District Survey (DHO, DEM)

To simplify the field work, integrated questionnaires were developed, one for household, one for businesses and one for public institutions covering all of the areas above. In addition a set of questions for the focus group discussion was developed covering all the relevant areas specified above.

3.2 Methodology

3.2.1 Timing

Due to the staged nature of the project implementation, with Kandeu and Mandrade being selected for delivery in 2016 while Thendo and Gola selected in 2017, the market assessment was conducted in two stages. This approach allowed for the completion of field work in the first two locations to occur sooner. Furthermore, conducting a market assessment in Gola and Thendo, in early 2016, may raise expectation that these projects will be implemented sooner than what is possible and possibly generate resentment in the community.

The major milestones for the MA for the first phase is described below

Major milestones	Completion Date
Design of Study, drafting questionnaires	January 18 January 19
Training	January 19
Questionnaire Pilot, Feedback, Redrafting, Translation	End of January
Field Work (Kandeu, Mandrade), Desk study	Feb 1 - 14
Data Entry	Feb 14 - 20
Focus Group Summary and Results	Feb 29
Phase 1 Analysis and write up complete	April 21
Phase 2 Survey adjustments	August 2017
Phase 2 Field Work (Gola Thendo)	August – Oct 2017
Phase 2 data analysis and write up complete	Oct – Nov 2017

3.2.2 Training, handling data, and sampling

Three separate questionnaires were developed for the MA aimed at households, businesses, and public institutions respectively. All questionnaires were facilitated by a trained enumerator with prior experience in similar field work. The questionnaires were piloted in a nearby village (not a SOGERV village) and revised prior to deployment to improve respondent and enumerator understanding of the options and ease delivery the questionnaire. The household and business questionnaire were then translated into Chichewa, the main local language in Chikwawa, to ensure consistent delivery.

Enumerators randomly selected households within the target village. Heads of households were asked to respond on behalf the entire household. Target respondents for businesses were the owners, although employees were allowed to answer if the business owner was not available.

A target of 60 households per location, on par with the SOGERV baseline methodology, was planned for the MA in phase 1. This level was determined to have 95% confidence. Due to time limitations, only 84 household questionnaires were completed in total (32 in Mandrade and 52 in Kandeu). While this limits the statistical significance of the results, the information gathered is still valuable for the purposes of the market assessment. For Gola and Thendo, there were a total of 131 and 99 household surveys completed, respectively.

Due to the small population of businesses at the locations, the field enumerators were instructed to survey all businesses in the area. In all 43 businesses were surveyed: 5 in Kandeu, 13 in Mandrade, 13 in Gola, and 15 in Thendo.

Each Household and business questionnaire took on average 30 minutes to conduct.

Institutional Surveys were very brief in nature and focused entirely on financial information for the facility. These were conducted at respective (health and education) district offices with staff who could speak on behalf of the facility. In Phase 2, community leadership was also surveyed who could speak about community resources to support the facility funding.

Focus Group Discussions (FGDs) were held to triangulate data and to explore some issues difficult to capture in a household survey format, for example potential social issues with the implementation of the project. A structured questionnaire was facilitated by the FGD lead with an assistant taking notes and creating an audio record of the proceedings. Two FGDs were held in each location lasting around 45 minutes each, with results compared and aggregated. In Phase Thendo and Gola, only 1 focus group was held in each location due to time constraints. In Gola, there were 15 participants and in Thendo, 13 (3 females, 10 males).

Figure: FGD underway in Mandrade

4 Results

4.1 Incomes and Energy Expenditures at Households

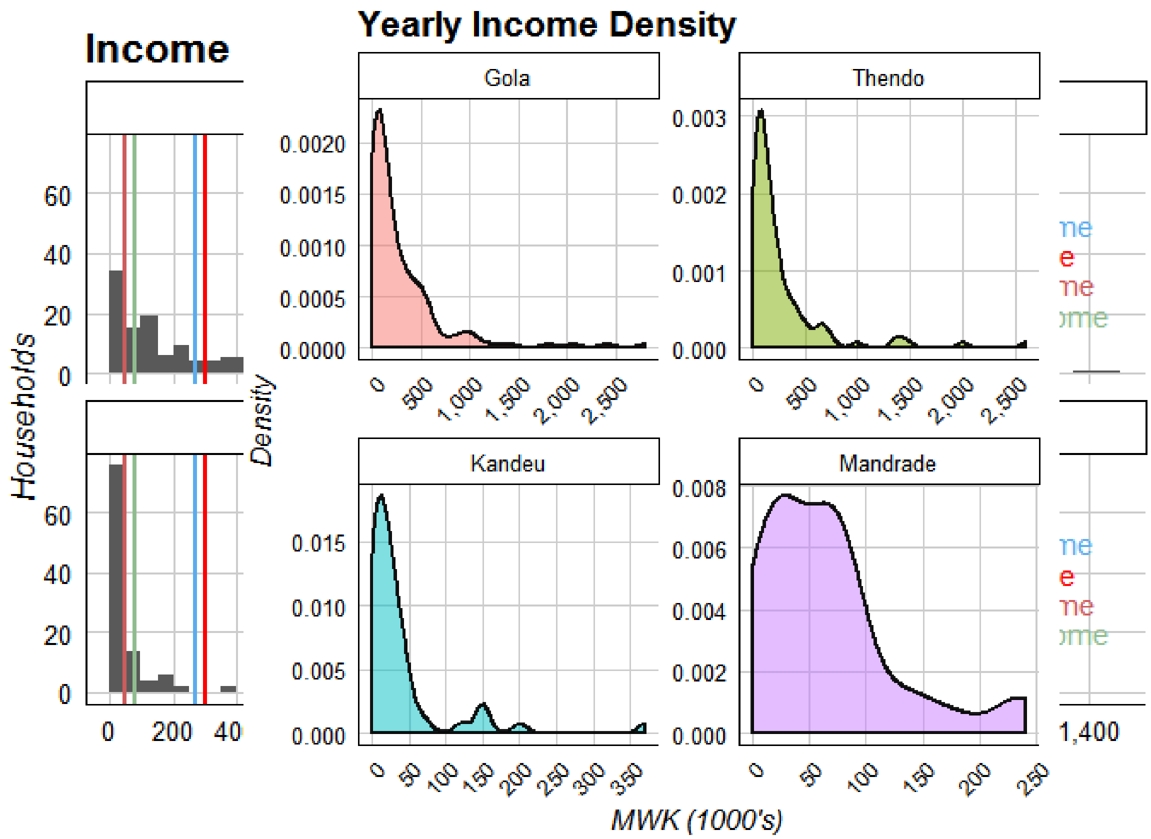
4.1.1 Incomes

From data taken from the SOGERV baseline it can be shown that incomes at both locations, Kandeu and Mandrade are extremely low. Self-reported yearly incomes for households are shown in the figure for both locations. This includes incomes from all sources (including agricultrual and non-agricultural income).

The situation for jobs, incomes, and finances in Thendo were discussed at the focus group discussion:

> **The households and businesses [in Thendo] access money through farming. Under crops, they grow cotton, "chitowe". Drought and floods are the common challenges faced when growing these crops. They also rear animals like, cattle, goat, pig and chicken. Animal husbandry faces Newcastle, Foot and Mouth disease and theft as the persistent challenges.**
>
> **They access finances through doing small businesses like fritters, butchery, tomatoes.**
>
> **Lack of electricity is a threat to butchery business as the meat always goes bad when it is not finished by the end of the day.**
>
> **Finances are not sufficient because generally farm produce proceeds are used to boost business capital. In cases where drought and pests have undermined harvest, there is little or no money to invest back into business.**
>
> **-Thendo FGD**

The vertical lines represents the mean income at each location for the income distribution plot below. Statistical data at each location is shown in the table below. Household annual incomes are extremely low, though Kandeu and Mandrade are signficantly lower on average than Gola and Thendo. The shape of the distributions are notable as well. Kandeu is heavily skewed towards very low incomes while the other location have relatively more households in higher income brackets. If one assumed income was connected to energy expenditure (which has not been supported here), the Kandeu would need products and service that are more afforable than other locations.


Income
Households
Yearly Income Density
Gola
Thendo
Kandeu
Mandrade
Density
MWK (1000's)

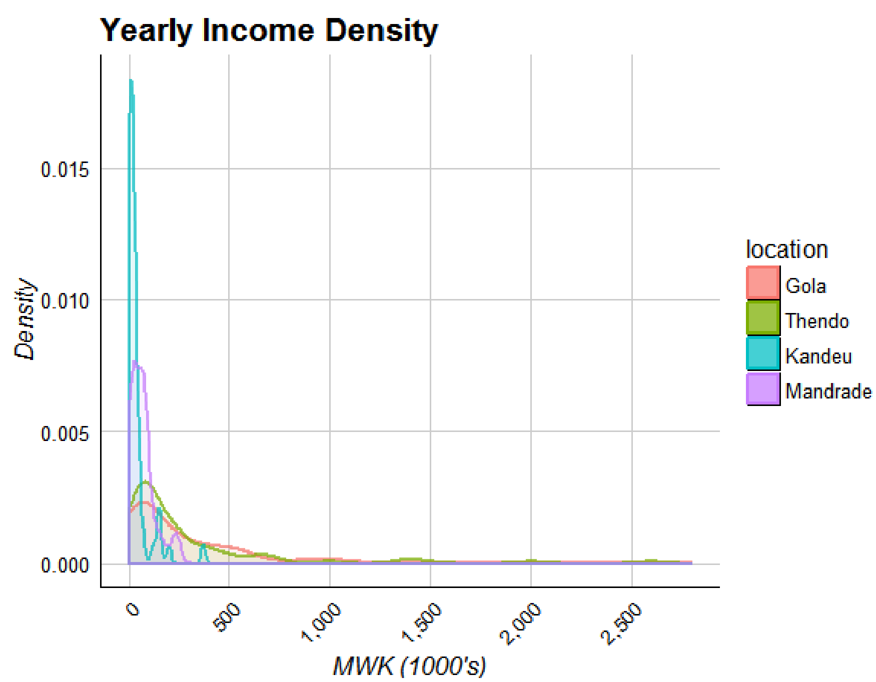

Yearly Income Density
Density
MWK (1000's)
location
Gola
Thendo
Kandeu
Mandrade

Table: Yearly Household Incomes

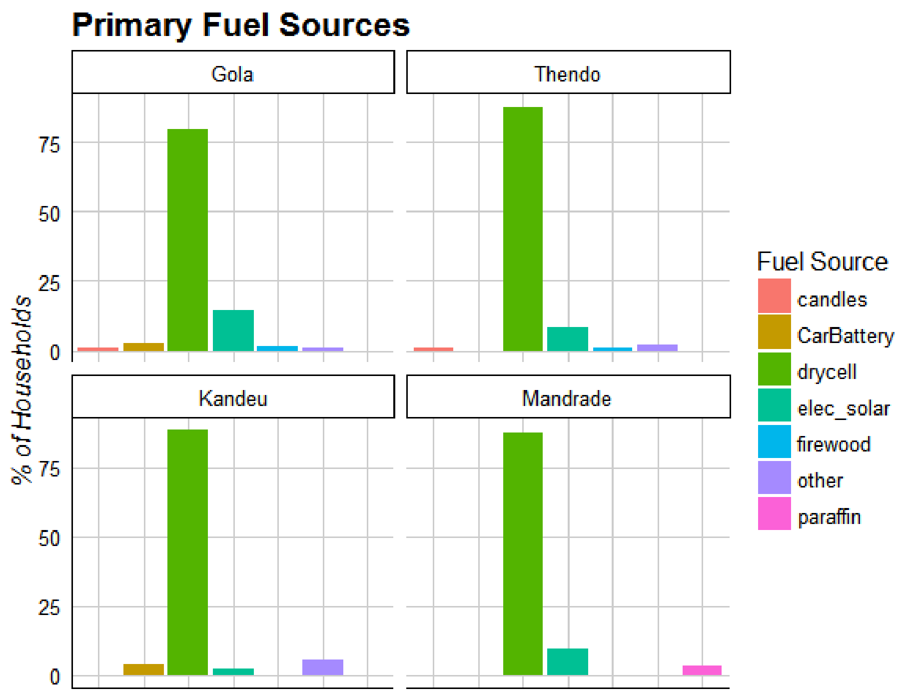
Location	Household Incomes (MWK/yrly)					n
	Trim.mean	sd	min	max	median	
Kandeu	36690	65059	0	370000	25000	104
Mandrade	67250	66512	0	240000	63500	64
Gola	204470	453728	0	2.8m	130000	127
Thendo	185583	409917	0	2.599m	138000	99

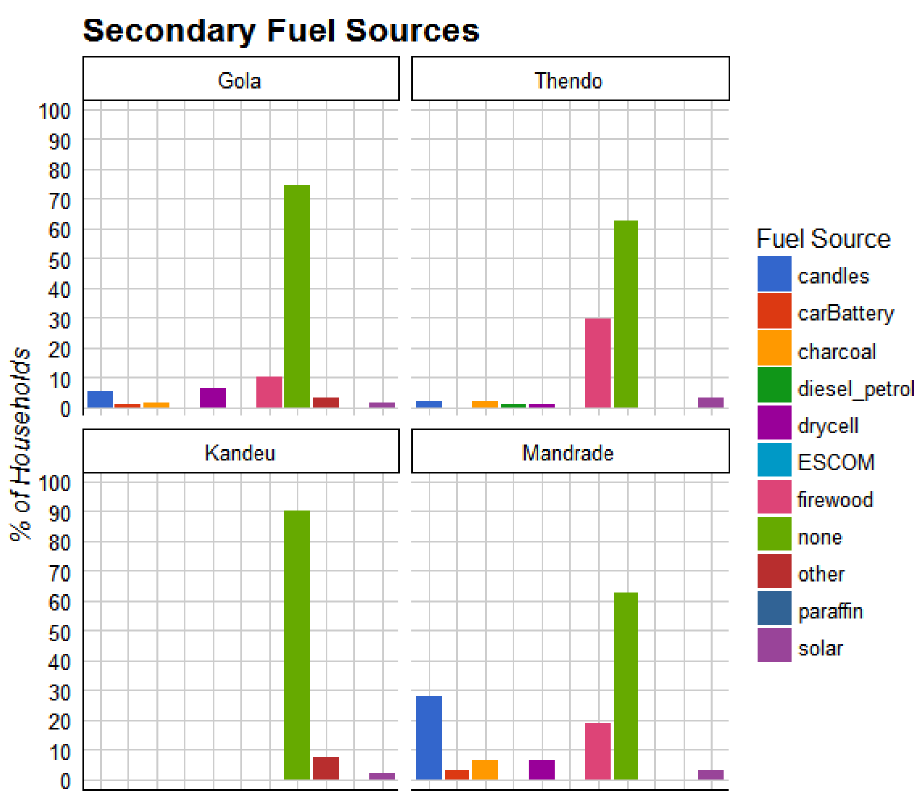
The low incomes are consistent observation from the Malawi Integrated household survey III[12] that the 'ultra-poverty gap' was 10.9% for the population in Chikwawa, the highest in the country. Another distinguishable feature of the distributions of incomes is the relatively high number of incomes at the lower end of the scale, especially in Kandeu.

4.2 Current Energy Use (Households)

Proportion of households using primary and secondary fuel sources for lighting are reported in the plots below. Overwhelmingly, dry-cell batteries are the main source of energy with around 80-90% of household selecting it as the primary source. Secondary fuel sources are more varied outside the common response of no other fuel source used for most households. Thendo (30%) and Mandrade (19%) both has a significant number of households using fuel-wood for lighting. In addition roughly 28% of households in Mandrade use candles.

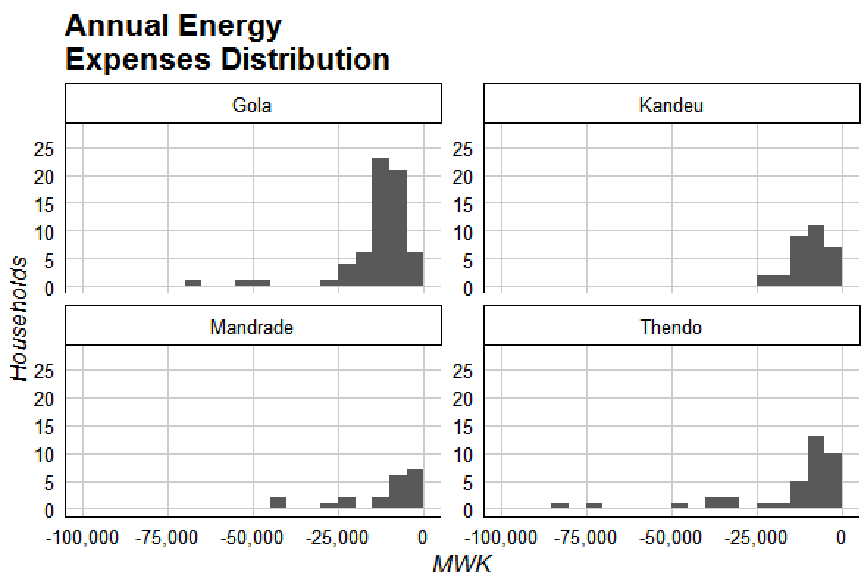
[12] http://www.nsomalawi.mw/images/stories/data_on_line/economics/ihs/IHS3/IHS3_Report.pdf

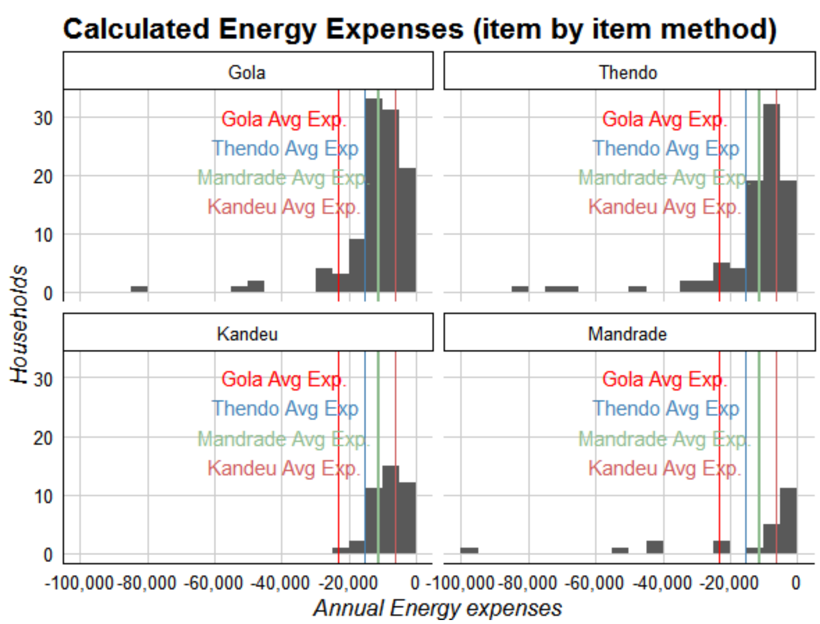

Primary Fuel Sources
Gola
Thendo
Kandeu
Mandrade
% of Households
0
25
50
75
Fuel Source
candles
CarBattery
drycell
elec_solar
firewood
other
paraffin


Secondary Fuel Sources
Gola
Thendo
Kandeu
Mandrade
% of Households
0
10
20
30
40
50
60
70
80
90
100
Fuel Source
candles
carBattery
charcoal
diesel_petrol
drycell
ESCOM
firewood
none
other
paraffin
solar

4.2.1 Energy Expenses

A basic assumption for this market survey is that willingness to pay for energy services is equal to current energy expenses. With this in mind, the current market size can be estimated and further segmented if a current energy expense can be determined. As it is a topic of interest for the project team, and is of academic interest, the results of a linear regression is also reported as it is often assumed that energy expense is correlated to income levels. Finally, the questionnaire included two approaches to collecting energy expenses, by asking total monthly energy expenses and alternatively by asking monthly energy expenses fuel by fuel, and report the differences in the responses.





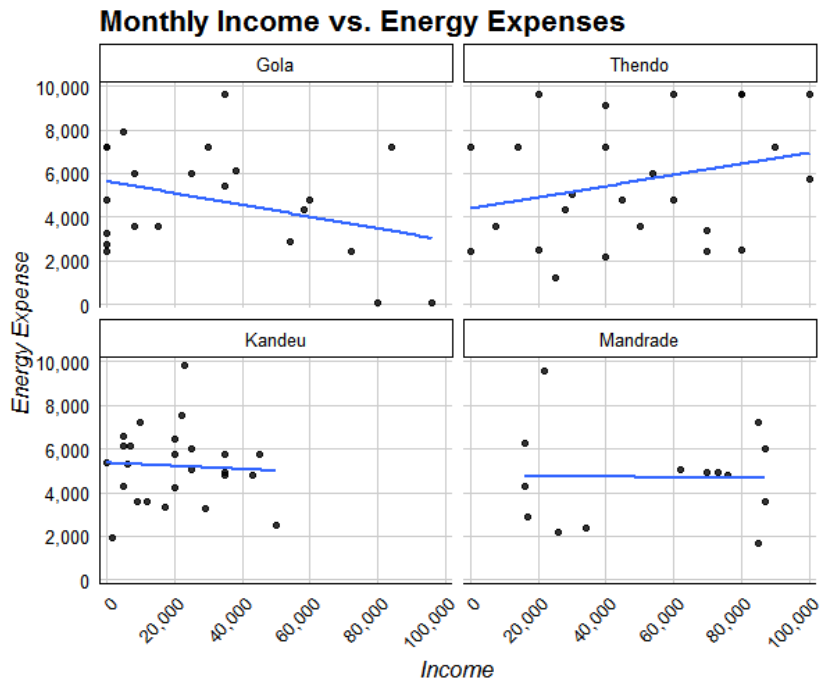
The distribution of annual energy expenditure for households for each village is shown in the first plot while the same distribution is shown when each energy type is asked about specifically (item-by-item method)[13]. As the item-by-item method is used at this point forward, additional data has been added: average yearly household spend has been plotted with the vertical lines. In both approaches, respondents were asked to recall their energy expenses over the previous month. The absolute error between the two approaches, when outliers are removed, was 6125 MWK, which is very high given the values considered. Summary statistics on energy expenses are shown in the table below:

Location	Yearly Household Energy Expenditure (for lighting) (MWK)					n
	Trim.mean	sd	min	max	median	
Item-by-Item Approach						
Gola	8232	14197	0	108000	7200	129
Thendo	9050	14033	0	84000	7500	98
Kandeu	7186	6245	0	24000	6480	31
Mandrade	4187	13021	0	43200	2340	20
Single Question Approach						
Gola	4711	10268	0	67920	0	129
Thendo	2270	13524	0	84000	0	98
Kandeu	8568	5637	600	24000	6600	31
Mandrade	5693	12786	1680	43200	6960	20

4.2.2 Relationship between Energy Expenditure and Income

The relationship between household annual energy expenditure and income is explored through regression modeling. A simple linear model is developed for each village to see what level of variation of energy expenses can be explained by income variations. In the plot below, model plotted in blue amongst the data points. In all cases, a significant model could not be supported with the available data. This result suggests that energy expenses for lighting should not be estimated with recalled income data. Speculation on the reasons for this lack of correlation is not pursued further here.

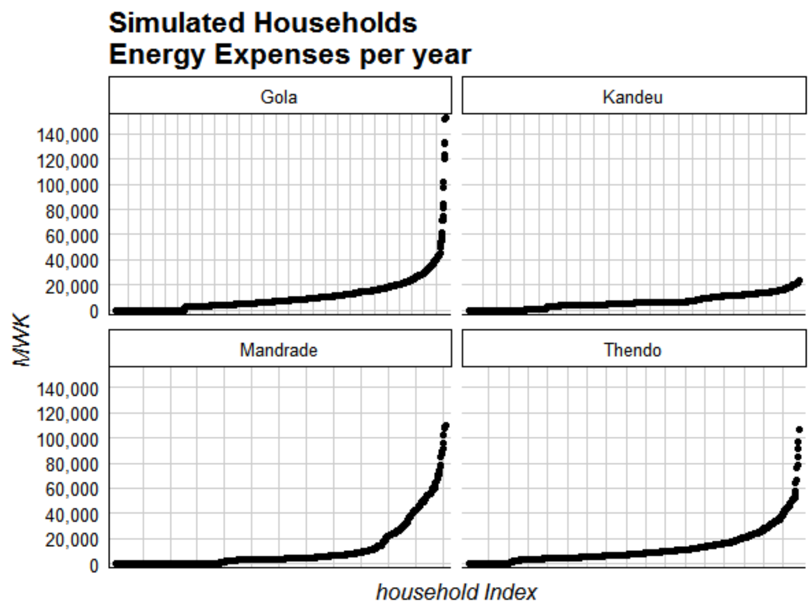
[13] Note the average expense vertical lines include the full dataset, not the outlier trimmed values shown in the table.



4.2.3 Market Size Estimation

Finally, the market size and segmentation is a desired for market size estimations. The approach used here is to extrapolate the number of consumers given the known distribution of energy expenses in each village. Local sources provided the number of households within roughly 5km of the village centre. Logspline density estimations were generated for each location using R and the logspline package and lower bounds set as zero[14]. Using the actual population numbers, household energy expenses were simulated for the full populations. This is shown in the plot below and ordered from lowest expense to highest expense per location for ease of visualisation.

[14] https://cran.r-project.org/web/packages/logspline/logspline.pdf



As a result of this exercise, a village wide total energy expense can be estimated by summing the household expenses. The yearly energy expense is estimated below (using 900:1 for exchange rates):

- Gola: 14,470,044 MWK = £16,078
- Kandeu: 3,039,956 MWK = £3,377
- Mandrade: 6,843,961 MWK = £7,604
- Thendo: 10,058,239 MWK = £11,176

Despite the desire to draw strong conclusions on the results, the market size estimates must be taken with a grain of salt. Assuming responses were accurate, there are several reasons to think that the estimate may be low. Any induced demand and consequent increased energy expenditure, for example from the use of superior products, will not be included in this approach. In addition, any acceleration of economic growth, due to the widespread availability of the electricity service is not included. Conversely, the full market is unlikely to be captured by any new business as fuel transition is not guaranteed.

4.3 Local Business Data

The MA involved questionnaires for 43 businesses in Kandeu (n=5) Mandrade (n=12), Gola (n=13), and Thendo (n=13). The mean business yearly income for all locations was 2,090,791 MWK while mean energy expenditure for lighting was 17,877 MWK. Detailed information is in the table below.

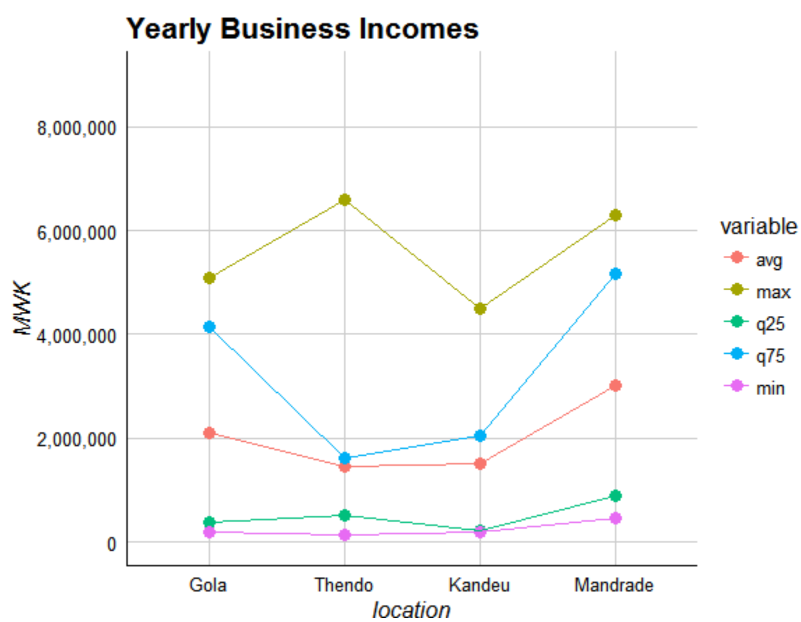
Table: Business Characteristics, by location

Location	Number	% of businesses owned by women	Avg. Age of Owner (years)	Education level of owners	Avg No. of Employees (%FT)	Avg. Income (yearly)	Avg. Energy Expense (yearly)
Gola	13	8%	33	< Std 8 7	2 (33%)	2,097,231	21,683

				Compl. Std 8 4 Some Secondary 1 Secondary Compl 1			
Thendo	13	33%	33	< Std 8 8 Compl. Std 8 3 Some Secondary 4 Secondary Compl -	2.6 (90%)	1,458,462	20,104
Kandeu	5	20%	27	< Std 8 4 Compl. Std 8 1 Some Secondary - Secondary Compl -	1.2 (100%)	1,500,000	19,680
Mandrade	12	31%	33	< Std 8 7 Compl. Std 8 4 Some Secondary 2 Secondary Compl -	1.9 (98%)	3,015,000	10,809

Table: Business Characteristics, by type (uncategorized businesses removed)

Business Type	Number in Gola	Number in Thendo	Number in Kandeu	Number in Mandrade	Avg. Income (yearly), MWK	Avg. Energy Expense (yearly), MWK
Grocery	9	7	4	9	2,490,828	18,314
Tea Room	2	1	--	1	667,500	26,040
Tailor	--	2	1		230,000	0
Bar/Drinks	--	1		2	4,800,000	19,720
Electronic Supply/Repair	1	--	--	--	330,000	96,000
other	1	4	--	--	2,182,500	5,808

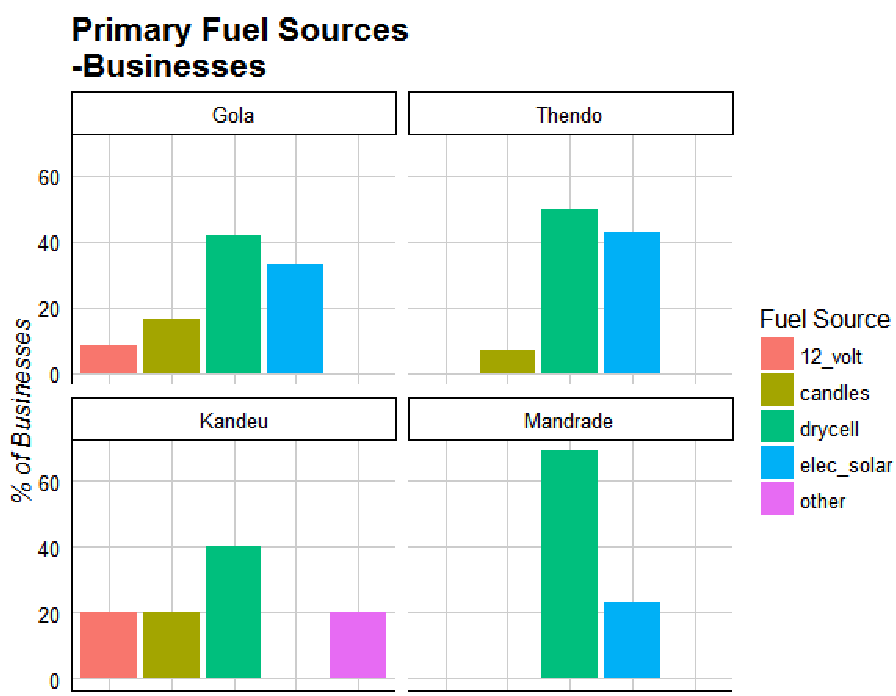


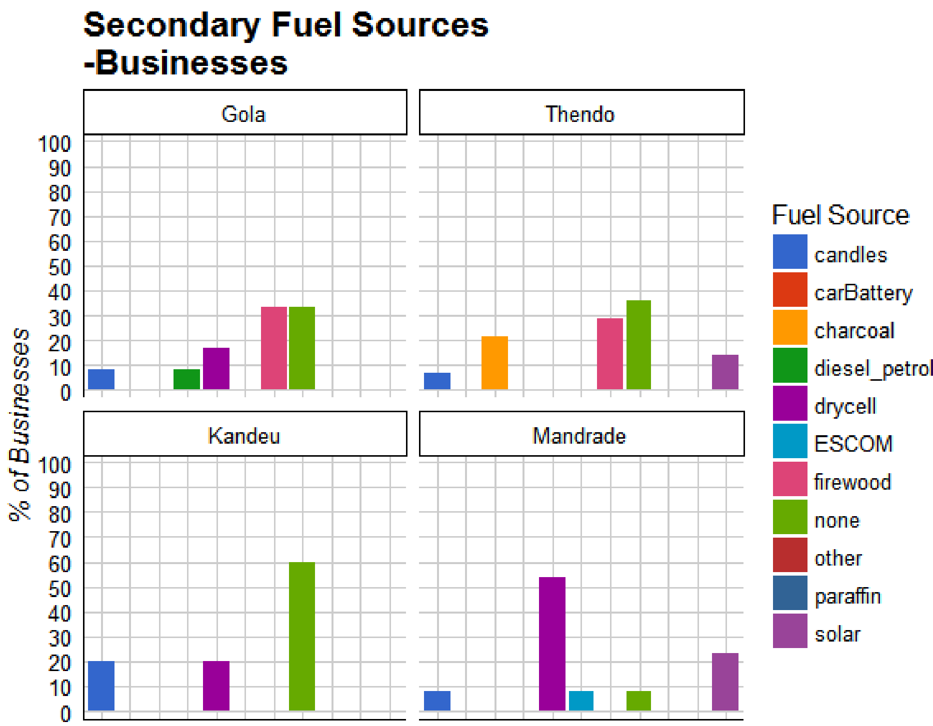
The MA has revealed current businesses at each location. The most common business is a grocery which has an average income of 2.49m MWK/year and spend 18,000 MWK on energy for lighting. Most businesses had very little energy expense, so any supply of electricity to these businesses may need to emphasize a marketing approach to show the value of electricity. The plot above shows the average (red line), minimum and maximum incomes for businesses at each location on a yearly basis along with the 25th and 75th percentile incomes.

Ownership was mainly by men and the average age of the business owner was about 30 years old. Education levels were very low: only one owner had completed secondary school and the majority had not completed standard 8 primary school. Finally, the average number of employees was between 1.9 and 2.6. Employed positions were mainly full-time roles, with the exception of Gola where only 33% of employees were full time.

4.4 Business Energy Use

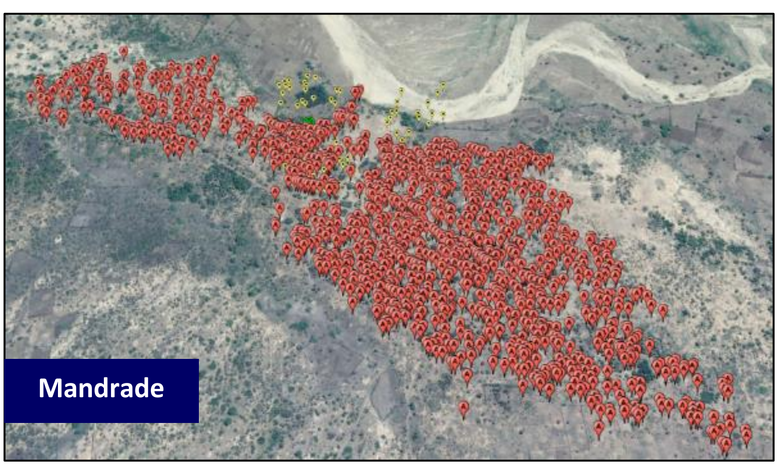
Proportion of businesses using primary and secondary fuel sources for lighting are reported in the plots below. Most businesses depend on dry cell batteries for lighting and a substantial proportion of businesses in Gola, Thendo, and Mandrade already have small solar PV systems. For secondary sources, firewood was used in about 30% of businesses in Gola and Thendo. Dry cell batteries, if not for the primary use, was a secondary fuel source. Notably, around 30% of businesses in Gola and Thendo had no backup fuel source; in Kandeu this is 60%.

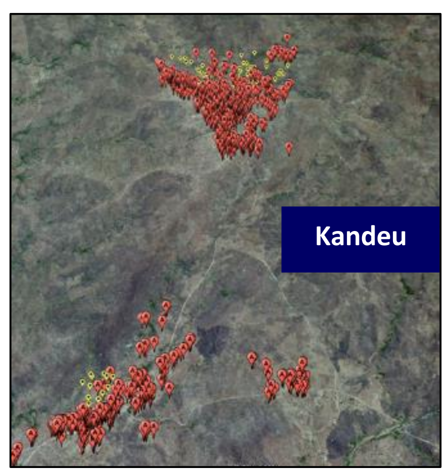




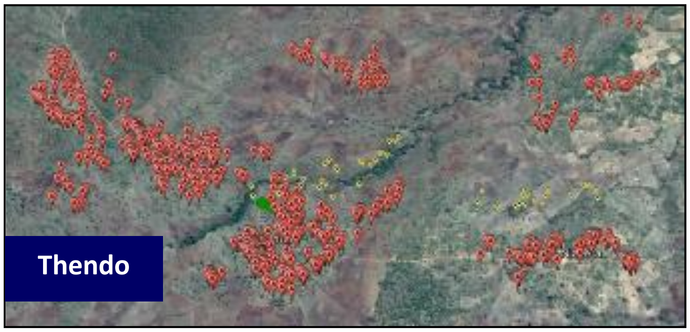
4.5 Populations in target locations

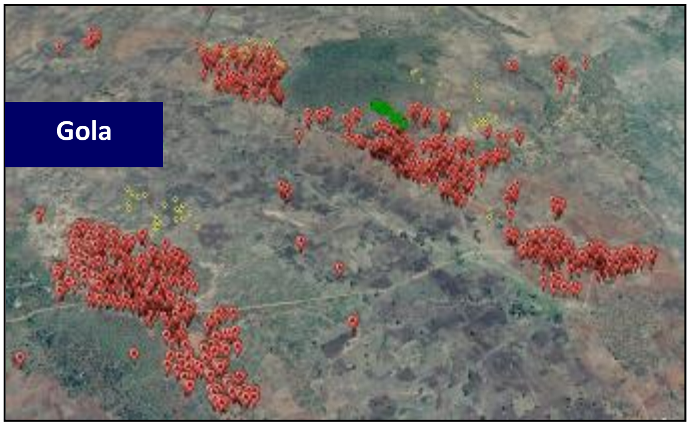
In Mandrade, the population is estimated at 3,037 in 604 households. The map tags all structures within 1 kilometer of the centre of Mandrade. This corresponds to an average household size of 5.03. In Kandeu, there are three nearby clusters of structures. The centre of the Northern and Southern clusters are roughly 3 km apart via the main road. The total population in the Northern cluster (Kandeu itself) is 906 (215 households). The South Western cluster (Liwonde) has 793 people and 160 households. The South Eastern cluster (Maganga2) has 444 people and 98 households. The





total population in this area is 2,143 in 473 households. This corresponds to an average household size of 4.53. The number of people per household were not determined for Thendo and Gola. Assuming an average of 4.53 people per household (as Kandeu), the number of people in Thendo is 3,810 in 841 households and the number of people in Gola is 6,043 in 1334 households.





4.6 Opportunities for productive uses energy

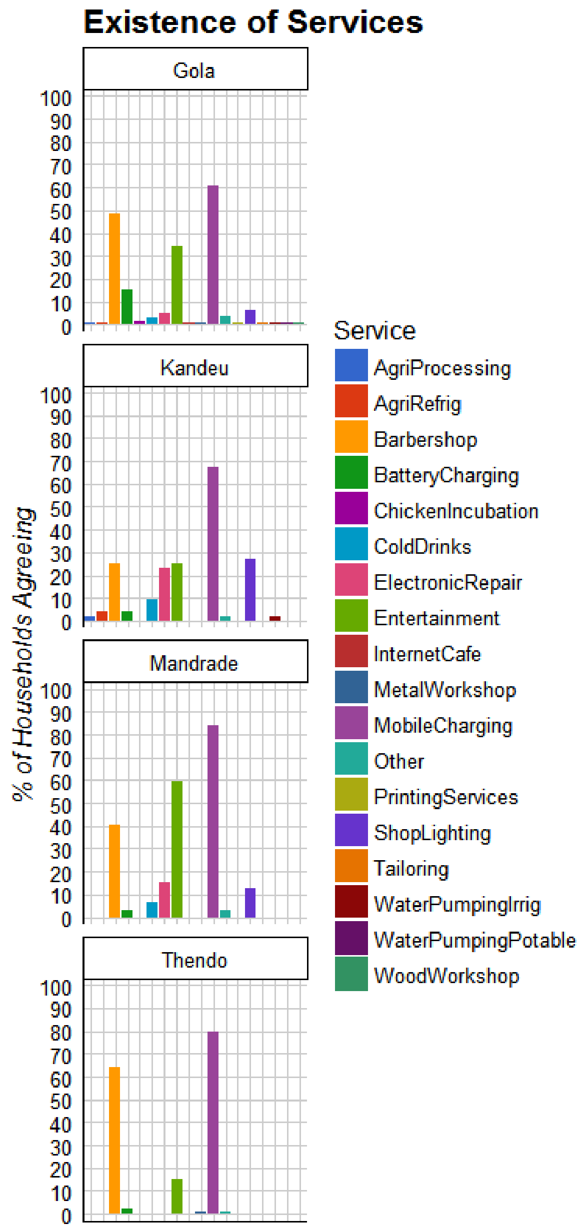
Productive uses of energy refer to activities that utilise energy as a key input to increase the economic productivity of the underlying inputs as opposed to non-productive activities which may only lead to increased consumption patterns. Promoting productive uses are desirable they can stimulate a market which can itself lead to ongoing economic growth. In energy access situations there are often many potential productive uses of energy, but their appropriateness can be localized. Several prominent references provide sources of inspiration for productive uses[15,16,17]. In addition, the SOGERV needs assessment and baseline activity provided qualitative feedback on the types of activities which might be supported in each community.

Blending potential uses for energy is a strategy desired by the SOGERV project to ensure diversity of income sources as well as to meet community needs. The MA sought to identify opportunities to provide a market-based solution for a desired service, in which energy is a key component, but would likely have a local market to sustain its operations.

[15] Lecoque, D., and M. Wiemann. "The Productive Use of Renewable Energy in Africa." European Union Energy Initiative Partnership Dialogue Facility (EUEI PDF) (2015).
[16] Brüderle, Anna, Benjamin Attigah, and Mirka Bodenbender. "Productive use of energy–PRODUSE a manual for electrification practitioners." Eschborn, Germany: GTZ (2011).
[17] ESMAP, "Productive Use of Energy – PRODUSE Measuring Impacts of Electrification on Small and Micro-Enterprises in Sub-Saharan Africa" *Eschborn, Germany: GTZ* (2013).

The MA questionnaires determined the existence of productive uses already in each location. It was assumed that existence of a productive use already in place means any new activity would face competition, a key factor in determining the viability of the business idea.

After existence was known, both households and existing businesses were asked about the prospect of the service being provided in the near future. Households were asked how likely they would be to pay for the services from a business that provided the specific service. They were not given any particular price for the service nor were they asked to provide a price. Their response was understood to be a general level of interest for that business associated with a willingness to pay for its service. In contrast, businesses were asked how successful, defined by level of potential profits, that a business providing such service would be. This was interpreted to mean the business' general interest in potentially providing the service as well as likelihood of profitable operations.



The list below indicates the specific productive uses which were identified. In addition, respondents were able to identify their own productive use.

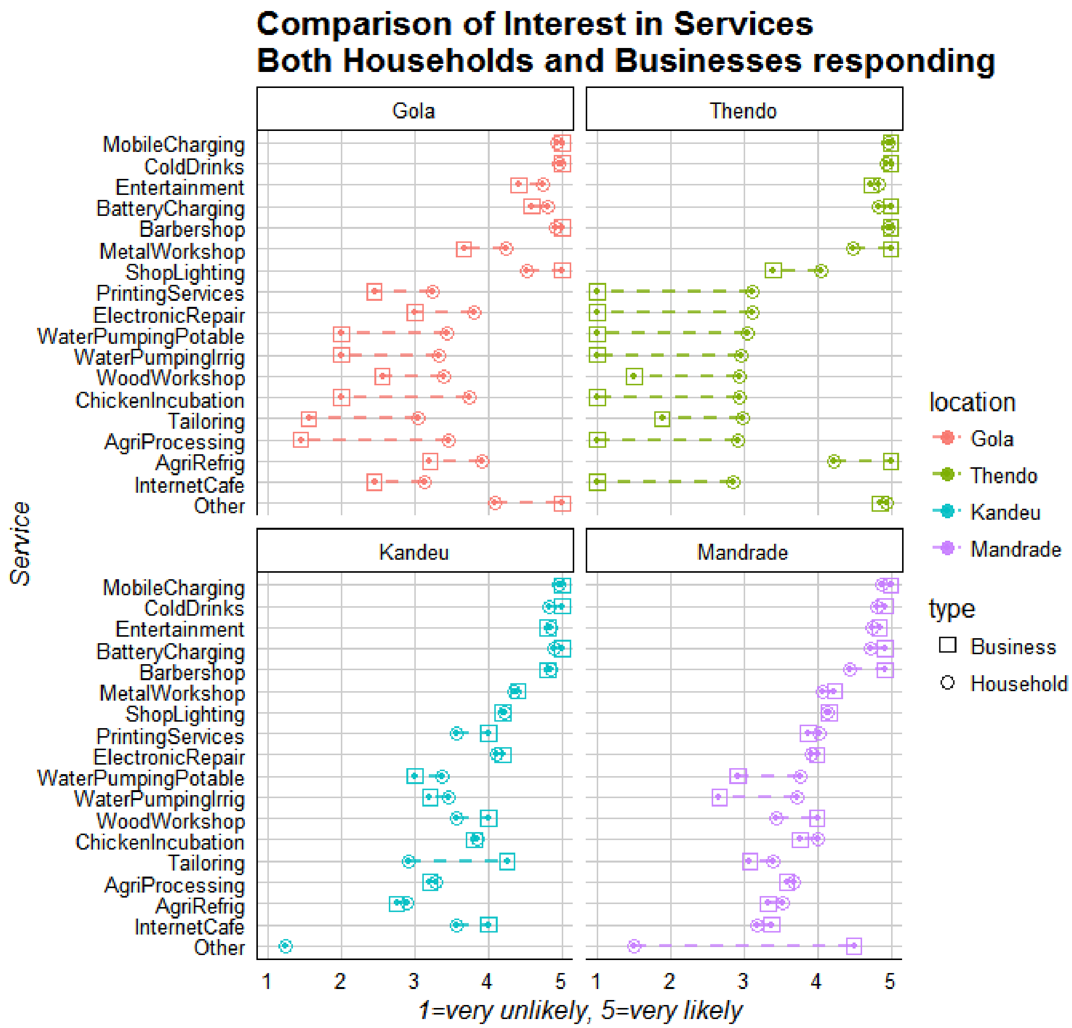
- Battery Charging
- Tailoring
- Cold Drinks
- Agricultural Cooling
- Agricultural Processing
- Entertainment
- Mobile Phone Charging
- Barbershop
- Water Pumping for Irrigation
- Water Pumping for Potable Water
- Chicken Incubation
- Internet Café
- Printing Services
- Wood Workshop
- Metal Workshop
- Shop Lighting
- Electronic Repair

4.6.1 Existence of productive uses

Both households and businesses were surveyed on the existence of existing businesses at each location as shown on graph (results shown from households only). In all locations there was already some form of mobile phone charging and a barbershop. Although note everyone agreed, there is likely a shop showing TV or playing music at Mandrade, Kandeu, and Gola. Other productive uses are unlikely to exist with very few respondents identifying them. Business modeling should therefore expect some level of competition with the activities currently in existence.

4.6.2 Interest in productive businesses

Households and businesses were surveyed on their interest levels in various productive uses if they were to be established at each location. Households were asked whether they would be willing to pay for the services from each business. Businesses were asked a slightly different question: how well a business doing said activity would fare if it were established (or expanded) at the location, specifically in terms of its likelihood to be profitable. The results are shown on the plot below, for each location. The squares represent the average response from businesses; the circle is the average response from households.



While there were some variations in the lower scored activities, the higher scored activities were remarkably similar at all locations: Mobile phone charging, cold drinks sales, entertainment provision, battery charging, barbershop, metal workshops and shop lighting. There was near agreement between business owners and households in their responses, except in the case of Gola and Thendo's lower scored items where consumers consistently rated these higher than businesses. There is no obvious explanation for this so it has to be assumed either that local businesses are not yet aware of a market for these services or that consumers are unaware of the business constraints for establishing the service.

While the results offer a good starting point for supplying a local business with electricity, it is no replacement for a full business plan around the idea. Further information is needed on the likely income, expenses, and market size of each of these businesses to determine its viability. This task needs to be taken up by the project or local partner prior to implementation.

Recommendation

- The **highest scoring productive uses** were mobile phone charging, battery charging, entertainment, barbershop, metal shop and shop lighting. The high scoring uses need to be passed on to the technical design team for consideration for standalone solar PV system design. Furthermore, the development of business plans for each of these activities is needed to ensure there is an economic basis for the investment.

4.7 Demand for specific energy-supply products

Seven products were introduced to households and businesses to determine interest and potential price for the products. The products ranged from small, single LED solar lantern to a solar home system to a mini-grid connection. The products inherently provided increasing levels of functionality and have different underlying capital costs. Images were provided within a printed survey aid and were described at a high level; read aloud by the enumerator. Although images and functionality were taken from specific products, no product brand name was used in the description. As with the rest of the questionnaire, all descriptions were read in the local language - Chichewa. An example of the description provided is reproduced in the box below (full descriptions can be found within the questionnaire annex)

Box: Sample product description

[READ:] OBJECT 5…

…contains a solar panel 5.4 watt panel which you secure to the roof of your house. A battery pack stores the energy from the solar panel. There are two fixed lights which you can place in two separate rooms and you connect with included wires. They provide a wide light. These lights have two modes: on "high" the lights produce more light and can be run both for about 7 hours per evening. On "low mode" they can be on for 24 hours. In addition, the system comes with two switches for the lights to easily turn them on or off. The system also comes with a portable lamp which can be charged with the system and provides around 5 and a half hours of light per evening. Finally, the system has an adapter so mobile phones can be charged.

In general, the products or equivalent product are available locally. Comparison of some, such as the mini-grid, would require development rather than purchase. The products can be class as follows:

- Object 1: Single small, ultra-affordable solar lantern. Task light, narrow light angle.
- Object 2: Single small, ultra-affordable solar lantern. General light, wide light angle.
- Object 3: Portable room light solar lantern. Larger than previous lights. Provides limited mobile phone charging
- Object 4: Portable Battery kit with two lights and a mobile phone charger. No solar panel – meant to be recharged at a charging station with a kiosk model.
- Object 5: Pico solar home system with a very small solar panel. Two room lights and a portable lamp. Mobile phone charging.
- Object 6: small solar home system, providing roughly 10x the energy of the previous object. 4 room lights and a very limited ability to use energy efficient household appliances (such as fans or televisions)

- Object 7: mini-grid connection providing a near-grid level of access, but no high consuming devices such as hot plates, refrigeration or air conditioning.

After reading the descriptions with each object questioning would begin. The respondents were asked to name a "fair price" for rental of the object for one month and were then asked the probability that they would be able to afford this amount during this very month. A similar line of questioning followed asking instead about price to purchase outright and ability to purchase the object during this very month. The only direction given to the respondent was that a "fair" price was defined as "the price you would expect to pay in this area". For the mini-grid connection (object 7), only a monthly access price was elicited.

We recognize that there are several shortcomings in this approach including: potential gaming in the response[18], lack of knowledge due to unfamiliarity with the objects, and increased burden to calculate value and price, to name a few. Despite these potential limitations, we take the prices quoted as an indication of "willingness to pay". Due to time limitations, only limited efforts were undertaken to explore the connection of price quoted (1st question) to the higher ability to pay (2nd question), though we expected that including the question may have influenced respondents to providing a more realistic answer.

Objects

4.7.1 Willingness to pay

4.7.1.1 Households

The willingness to pay for the rented objects are shown in the figure below. Reported prices for each object (1 through 7) are shown in ascending order on a scale from 0-80,000MWK. The plot shows both the desired price for renting the object for the year and the desired price for outright purchase.

Overall, pricing is very low with most respondent reporting prices well below actual costs. Average prices increased with increased functionality as expected. As objects become more functional/expensive, respondents begin answering "don't know" more often, indicating that it becomes more difficult for them to value the object.

The willingness to buy particular objects seems to agree with higher income levels; Gola and Thendo are closer to the actual prices than Mandrade and Kandeu.

The table provides average prices for each object at each location. Note the willingness to pay for rental of objects is reported as monthly amounts (not yearly as shown in the plot).

[18] Several scenarios can be imagined: 1) Respondents could produce a higher price, beyond their hidden private value, in an effort to influence designers to do business at the location, 2) Respondent could produce a lower price than their actual hidden private value in hopes that the project underprice the products.

Mean Expected Price for Buying or Renting Specific Products (Households)

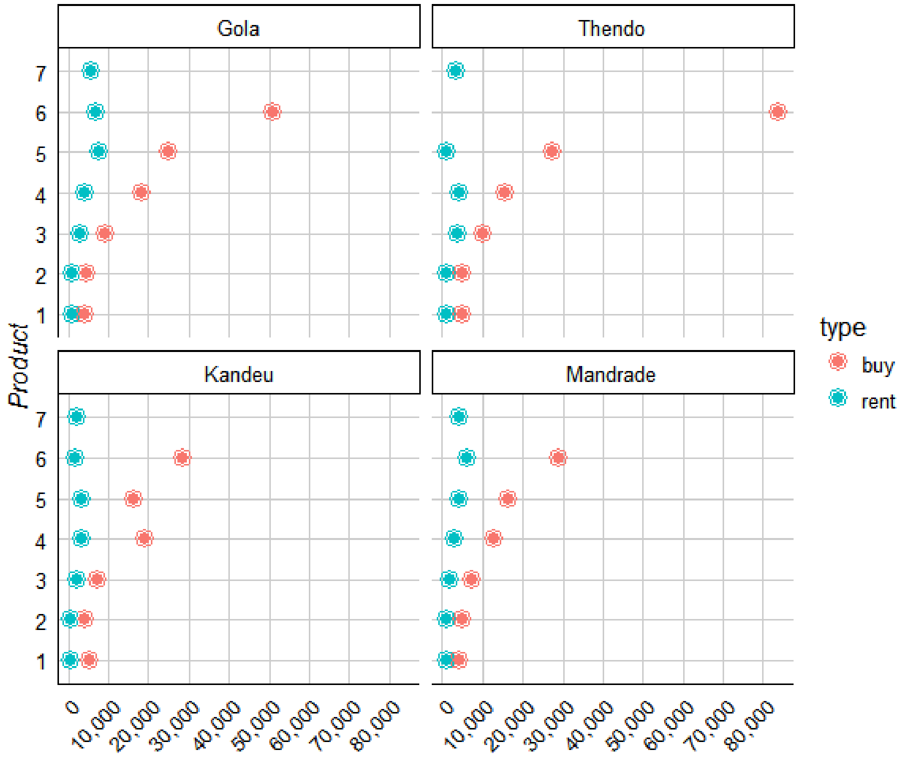


Table: Average Willingness to Pay (Rent) for 1 month of service

Location	Object	Buy	Rent
Gola	1	4185	785
Gola	2	4434	932
Gola	3	9080	2833
Gola	4	18183	3916
Gola	5	24888	7625
Gola	6	50827	6736
Kandeu	1	5403	5589
Kandeu	2	4065	632
Kandeu	3	7150	650
Kandeu	4	19000	2083
Kandeu	5	16250	3355
Kandeu	6	28333	3440
Mandrade	1	4313	1875
Mandrade	2	5057	2070
Mandrade	3	7478	1207
Mandrade	4	12895	1124

Mandrade	5	16568	1959
Mandrade	6	29142	3173
Thendo	1	5006	4004
Thendo	2	5174	6304
Thendo	3	10235	4004
Thendo	4	15600	1056
Thendo	5	27475	1068
Thendo	6	83695	3833

The relative WTP between rental and purchase provides a value input into the business model. Where the WTP (purchase) is too low, a financing or rental arrangement using the WTP (rent) can provide an alternative.

In the table below, for objects 1 through 6 a reasonable leasing price (rent-to-own) for a 12 month period, or an ongoing rental price is estimated and compared to the WTP (rent) price. A 24% interest rate and 25% markup is assumed on all financing arrangements. A 50% markup is assumed on a cash sale[19].

Table: Suggested Pricing for Objects

Obect	Cash Sale	12 month lease, monthly price, MWK	Rental price, Monthly
1	8000	700	400
2	15600	1600	950
3	54600	5600	3400
4	143000	14500	8800
5	183300	19000	11300
6	373000	Not considered	9500

*Note – base costs only, no markups included. Priced over a longer (~5yr) payback period.

When asked for the WTP (purchase) respondents valued the objects higher, but still not high enough meet the cash sale price. As the objects get more costly, the difference in average WTP (purchase) and the respective cash sale price grows. This can be seen as a lack of knowledge on the true pricing of the objects – this is understandable given the low electricity access rates.

[19] These assumptions are used throughout the SOGERV business model. Equivalent products are used if costs were not immediately available. Although wholesale prices may technically be lower, we use a price buildup which would be required for sustained distribution/retail operations.

4.8 Familiarity with different payment arrangements

Given the expected low incomes in the target villages, the MA sought to learn more about the familiarity of different payment arrangement for households. The questionnaire included a section that defined the three payment arrangement: fee-for-service (renting), rent-to-own (lease), and a cash sale. Respondents were asked to rate their familiarity with the arrangement and then asked if they had ever been in such an arrangement before. Results are shown in the tables and figures following.

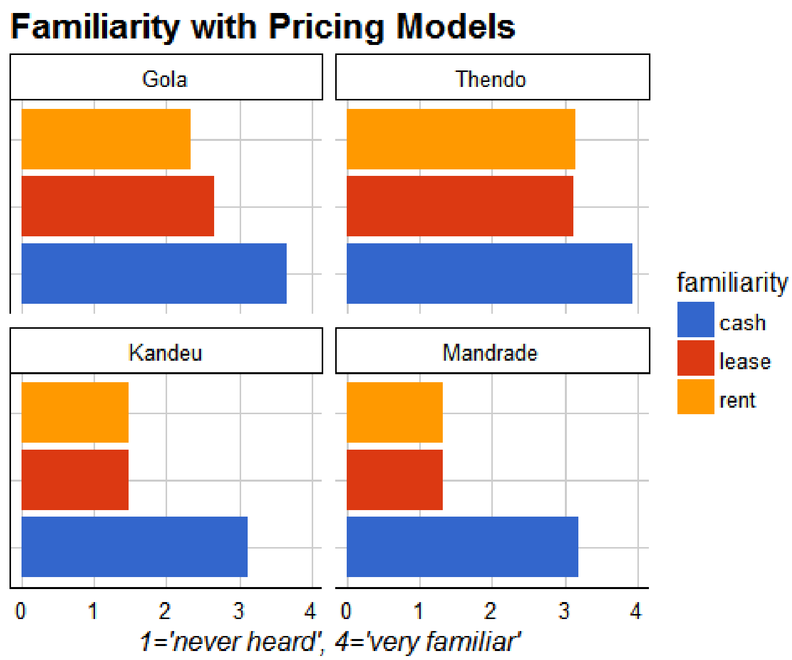
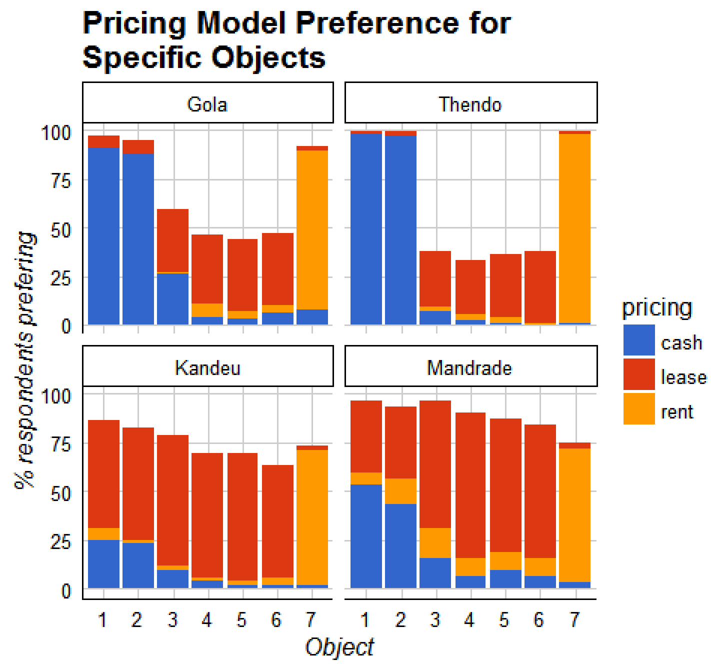


Table: Familiarity with Payment Arrangements

Location	Payment arrangment	Avg. Familiarity (1 = never heard of, 4 = very famliar) mean
Kandeu	Fee-for-service	1.48
	Rent-to-own	1.48
	Cash sale	3.19
Mandrade	Fee-for-service	1.31
	Rent-to-own	1.31
	Cash sale	3.19
Gola	Fee-for-service	2.34
	Rent-to-own	2.66
	Cash sale	3.65
Thendo	Fee-for-service	3.14
	Rent-to-own	3.12
	Cash sale	3.93

Cash sales are by far the most familiar and the households have had the highest levels of past experience with this format. There is again a distinction between Kandeu/Mandrade and Thendo/Gola in terms of the leasing and rental arrangements. Both Kandeu and Mandrade are quite unfamiliar with this format, so consumers may need training to make them comfortable. This issue is less apparent in Gola and even more so in Thendo where consumers appear to be quite comfortable with financing arrangements.

When we followed up with the respondents on their preference for the pricing for each object, cash purchase and leasing was clearly preferred. Cash purchase was preferred for the smaller objects and this shifted to leasing as the objects gained functionality. Renting was only preferred for the mini-grid connection.



- ❖ ***Recommendation:*** The low WTP for the available products would imply that a rental or leasing payment options were pursued. The preferences to own products will have to managed since there is little ability to do so at current expenditure rates. Given the low familiarity with these arrangements, it necessitates the business model include training/marketing around how the financing arrangements are established in some cases.

4.9 Availability of finance

With the likely dependence on some form of finance to gain access to potential energy-supply products, we explored the current availability. On average, respondents with debt owed 34,064 MWK in principal and were paying an average (unweighted) interest rate of 281.4%/year.

Of the households surveyed, only 8% reported having a bank account and 13.7% currently had some form of debt. In the table below, the surveyed household financial data is shown. Many of the debts have monthly interest rates and require 20% interest or more with some as high as 50%/mo. The highest interest rates were paid to local loan sharks (1200%/yr). Village savings and loan groups were most commonly found to exist within the villages, followed by village banks. Commercial banks were very uncommon and did not exist at the villages. However, some respondents had borrowed from a commercial bank in the past and the average interest rates were fairly low, in comparison to alternatives, at 62.5%/yr on average.

Table: Household Finance Data

Location	N	N with debt	% HH with some form of debt	Average debt amount owed (MWK)	Avg. yearly interest rate paid	% of HH with short payment terms (1 month)	% of HH with bank account

Gola	131	7	5.34%	55000	532%	86%	4.6%
Thendo	99	25	25.25%	35857	251%	66%	9.1%
Kandeu	52	5	9.61%	24300	192%	80%	11.5%
Mandrade	32	6	18.75%	11500	168%	83%	12.5%

Table: Village Financial Institutions

Financial source	Respondents reporting existence of institution within the village				Avg interest rate/yr
	Gola	Thendo	Kandeu	Mandrade	
Commercial Bank	0%	0%	0%	0%	62.5%
Family/Friend	Not asked				120%
Loan Shark	76%	52%	15%	38%	1200%
Village Bank	85%	42%	50%	34%	243%
VSL	89%	91%	56%	91%	431%

At the FGD, the participants asserted that saving money is very difficult as much of the earned income goes towards the purchase of food. Investment is minimal for the same reason. They confirmed that the main sources of finance are village bank, ASKA and loan sharks.

- ***Recommendation:*** With the low levels of debt, ownership of bank accounts, and high interest rates, it is clear that financial capacity in the villages are extremely limited. The intended energy businesses established by SOGERV will therefore need to be able to manage a financing arrangement in order to make products/services affordable by the local population. Depending on the capacity of the local operator, the provision of finance through the business to the local population may be a route to diversification.

4.10 Supply Chain

Several key aspects of the supply chain for a community renewable energy provider were explored in the FGDs. This included the existence of skills for the repair of small power systems, and availability of components used in solar home systems. With respect to skills, lack of technical knowledge of how solar PV systems work has been a reoccurring issue in Malawi. In rural villages education levels are very low and the operation of electrical systems is not commonly trained until tertiary education.

Local availability for the components of the solar PV systems is often a requirement because working with international suppliers is typically out of scope for many rural system operators. Failure to source a part, and skilled technician to replace the part, may result in a prolonged (or indefinite!) outage of the system. Of course, this scenario has major implications on any business based on the use of the generation power.

There was only one person in Kandeu which could be identified by the FGDs with skills sufficient to install or repair solar home systems. It was guessed that they were not MERA certified. In Mandrade no such resource exists; the nearest source of expertise was in Kakoma, roughly 10 km away. In both Gola and Thendo each three persons were identified as having some skills to repair small electronics, but did not have any formal training. Between the four villages the FGDs identified 10 skilled people, or were thought that could be trained, to repair electronics such as radios and mobile phones. On further probing, it was noted that the education system does not provide this knowledge and any learning that they had was self-taught or picked up informally from someone else.

- ***Recommendations**:* As it appears that skills levels are minimal, personnel at any business will need significant technical training to competently manage the installed power systems. A dedicated training provision is needed and would ideally cover all the major aspects of solar PV systems installation, operation, maintenance, trouble shooting. Since no technical training provision exists locally, a long-term training source should be identified and contracted to provide ongoing training on 6-monthly or yearly intervals for any personal responsible for operating the rural business. Even with this training provision, a maintenance/service arrangement should be established with a certified technician to support more complex technical issues that may arise.

Renewables equipment and sub-components were generally unavailable in the villages. The nearest source was Chikhwawa Boma, Mozambique, Nchalo and Blantyre. There were no local stock of this equipment. In Gola, there was a general feeling from the focus group discussion that lack of access was the major obstacle for people buying solar PV based products - currently they have to travel very far away to get it.

- ***Recommendations**:* The lack of current stocks of renewables equipment is not unexpected, as a rural market no suppliers have set up shop in these locations. Affordability has been a major issue so a more complicated business model (i.e. involving leasing or rental) is needed. Businesses setup up in these locations will require a supply chain setup for critical components. Suppliers will need to be sought out in Chikhwawa Boma or Blantyre if necessary for the main components (Panels, batteries, charge controllers, inverters). In addition, a sufficiently sized inventory should be kept for consumer products sold in conjunction with the business and to minimize the impact of replacement on the consumer service provision. This includes products such as pico-solar-products, 12V solar batteries for home use, small consumer appliances, LED and CFL lightbulbs, etc.

4.11 Other Considerations for the market

The FGDs discussed the consumer perceptions of existing renewable products available in the villages. This includes such products as solar panels, 12V batteries, solar lanterns and energy saver bulbs. There was a general consensus that the current equipment being used is of poor quality. The participants summed it up the challenge,

> "Many of us just know that this is a solar equipment but we cannot differentiate between the fake and the original. We are confused by these Chinese product but we are very hopeful that with your [CU] presence, we are going to get the right guidance."

In addition the inability to differentiate genuine products from fakes on inspection, it was suspected vendors are selling fake products at prices usually reserved for genuine products. The FGD participants also explained that relatively the high investment for a household in renewable equipment takes away from purchasing food, a critical alternative for the discretionary funds. Participants also noted that they were somewhat distrustful of solar PV technology as they have observed mobile phones being returned not fully charged from PV-based charging stations in the past.

Since experience with solar PV is very limited, consumers have a difficult time determining whether products were working as expected. In Thendo, it was noted by one FGD member that:

> "Solar is designed in a particular way, some panels may look big but produce less power. It is very difficult to comment on life of the equipment since none of us do own any equipment"

- ***Recommendations*:** Lack of consumer knowledge and the legacy of poor products in the market translates to a likely consumer wariness to buy new renewable products, despite their quality. An energy supply business will need to combine consumer training with sales efforts so that consumers are informed. Measures such as providing a warranty will reassure customers. SOGERV should provide general, community level training on renewable energy appreciate in order to dispel any misconceptions on solar products. The use of Lighting Africa approved products can assure quality standards are met, but the operator needs to be able to articulate difference between their high quality products and other low quality products which may be prevalent. Finally, economics for the household which buys any of the products needs to be clearly explained to the consumers so they can recognize the savings and value they get from products.

4.12 Market Segmentation with Specific Product Price Thresholds

With the range of incomes as well as energy expenditures for consumers within the respective markets, the project desires to better understand market for specific products that will be incorporated in to local businesses. At all locations, it has been established that the majority of consumers have very low yearly energy expenses, especially in the case of Mandrade and Kandeu [see sections 4.1, 4.2]. Since the likely prices can be estimated using the products which will be deployed, we likewise estimate the number of products and likely pricing mechanisms for this market.

To do this, a full population is estimated using the actual village size and based on the distributions of energy expenses in the village. Given there was no relationship found between income and energy expenses, we do not use income as a predictor in any way, and utilise the assumption that the old products and fuel sources will be substituted for the new products introduced by the project. Thus, future energy expense will be equal to or greater than current expense.

The project has identified four consumer products which have been targeted for deployment. Expected prices are given below for each product, competitive with the local markets. Although the intention is to offer 6 and 12 month lease arrangements, the analysis is simplified such that only the cash price and the yearly price for renting the products are shown.

Object and Description	Cash Price, MWK	Rental Price (per year), MWK
1 - Small Solar Lantern	8000	4800
2 - Small Solar Lantern with Mobile Charger	21000	13200
3 - Portable battery kit (PBK) with 2 lights and mobile phone charger	96000	38400
4 - DC Solar Home System (SHS) with 4 lights, mobile phone charging, radio, and task light	134000	78200

In the plot shown below, these thresholds are drawn in as horizontal lines and labeled. In the graph, each dot represents one (simulated) household's energy expenses over the course of one year. The cash price is shown as red while the rental price in blue. The y-axis has been limited to a maximum of 80,000, though in this sample there are 18 outliers. As is clear, the higher prices goods are not affordable at a cash price. The rental price for object 4 appears to be the maximum any one household would be able to afford.

Given these thresholds, the number of households who would purchase or rent the products can be estimated simply by adding those which fall between the thresholds. This is done on the cash purchase only scale and a renting only scale on the table below. The assumption used is that each household will purchase one product which is immediately at or below their budget. As is expected, the use of a financing arrangement (rental) means that considerably more households gain access to the products.

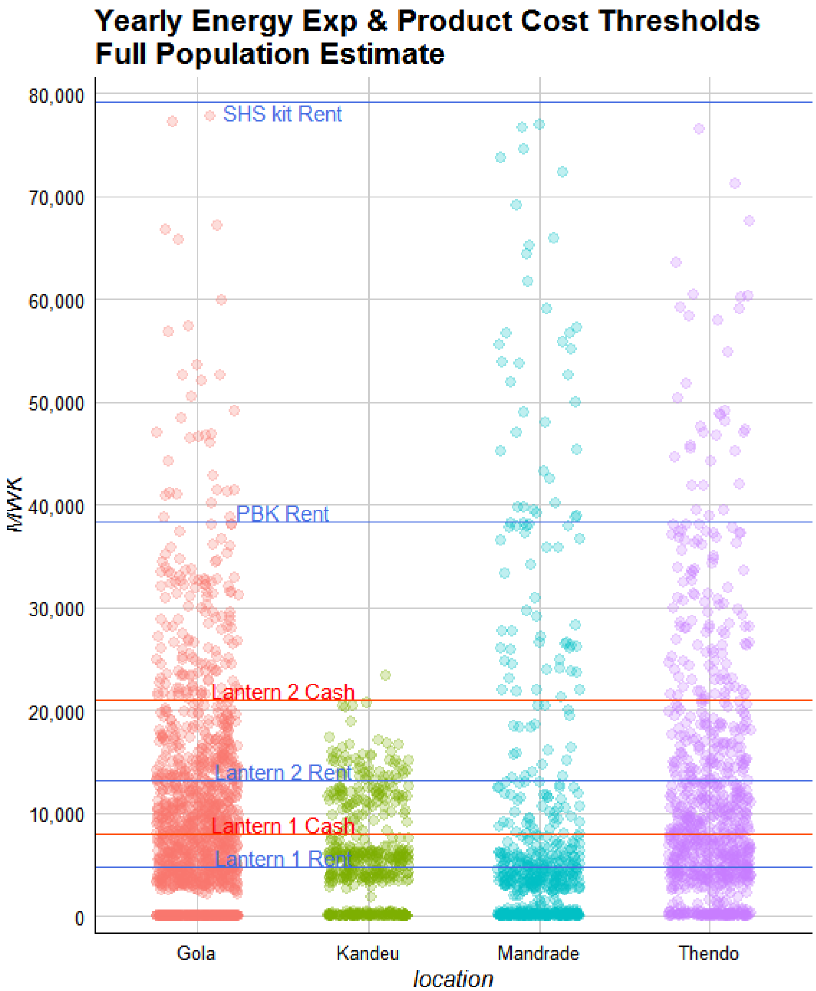


Table: Market Segmentation – Rent (price/year)

Object	Rental Price	HH (Kandeu)	HH (Mandrade)	HH (Gola)	HH (Thendo)
Total Number of Households		**473**	**604**	**1334**	**841**
1 - Small Solar Lantern	4800	206	126	458	327
2 - Small Solar Lantern with Mobile Charger	13200	62	63	325	208
3 - Portable battery kit (PBK) with 2 lights and mobile phone charger	38400	0	54	36	41
4 - DC Solar Home System (SHS) with 4 lights, mobile phone charging, radio, and task light	78200	0	9	10	4
Households which cannot afford any object		205	352	505	261

Table: Market Segmentation – Cash Purchase Price

Object	Purchase Price	HH (Kandeu)	HH (Mandrade)	HH (Gola)	HH (Thendo)
Total Number of Households		**473**	**604**	**1334**	**841**
1 - Small Solar Lantern	8000	142	66	440	270
2 - Small Solar Lantern with Mobile Charger	21000	5	103	170	134
3 - Portable battery kit (PBK) with 2 lights and mobile phone charger	96000	0	0	6	0
4 - DC Solar Home System (SHS) with 4 lights, mobile phone charging, radio, and task light	134000	0	0	0	0
Households which cannot afford any object		326	431	716	452

- ***Recommendations:*** For the business model design, product selection should err towards smaller systems which are less costly. Limited cash sales will be possible with the current availability of finance, to take on debt, in the villages. As a result, in order to provide access to more functional products, a financing arrangement will need to be offered by the installed business which allows either for a rent-to-own or fee-for-service. This will lower the income entry point for the products.

  As there was a preference and familiarity for cash sales, the less expensive products may be more appropriate for a rent-to-own arrangement with repayment terms that sufficiently lower the entry point. According to the current debt-owners, the yearly interest rate is nearly 100%, so any rate less than this could be considered acceptable. Given the nature of the project, a more reasonable rate could be offered down to the current Reserve Bank of Malawi rate set at 27%.

  For the current market, the cap on the yearly rental price appears to be very near the rental price threshold for the Solar Home System, or 78,200MWK where only a few families will be able to afford the cost. Although there were a few outliers, it is unexpected that many families will be able to purchase the PBK and SHS products outright.

  With the low level of competition, lack of existing renewable energy products, and WTP, products targeted at the right entry point should be in high demand. Emphasis on marketing of products (in some cases consumer training), and satisfying consumer relations will overcome current barriers and improve potential of the business to capture more of this market. With success and profits made as the assets of the businesses become fully utilised, competition should be expected. The business will need to differentiate itself as a provider of high quality products and services with high reliability to avoid undercutting with lower cost and quality products.

4.13 Feedback on new energy project in village

Participants in the FGD recognized the value of introducing renewable energy into their village which was expected to have general development advantages. The community was expected to benefit as new businesses will be possible including phone charging, barber shops, chicken incubation and sales of cold drinks. Ability to watch TV, especially football matches, was an exciting prospect. At households the participants cited savings that would be possible when switching from dry cell batteries to devices with solar and the ability of their children to read at night. The community thought the availability of lighting at the health centre would help patients receive better treatment. Some notable benefits which were cited include:

> "I am very thankful to Concern Universal because of the rent to own setup which will help many people having low incomes to afford purchasing the renewable energy equipment."
>
> - **Kandeu**
>
> "The community will benefit from a boom of businesses like phone charging barber shops and cold drinks(minerals, fizzy drinks, local beer) which will be accessed locally. People will also be able to rear chickens using solar.
>
> Diesel maize mills can also be replaced by a low cost solar powered maize mills.
>
> Many are times when people fall sick at night. The availability of solar energy will ensure that patients receive treatment under sufficient lighting at night from the health post.
>
> **- Gola**

Despite these benefits the community expected some challenges.

First, the FGD was worried about prices that would be charged and the possibility of overpricing. They suggested the Project and business itself publicize recommended prices.

Second, they expected that the installation of solar PV systems may attract thieves. The community suggested that hiring guards, utilising community policing, and installing physical security systems such as locking up items to restrict access – wherever feasible.

Third, the participants warned that the selection of the local entrepreneur, who would run the business would need to be properly screened to ensure that 'defaulters' could be screened out.

Fourth, the participants suggested that prostitution, and STIs, may increase due to a more substantial nightlife which is expected due to electrification.

Fifth, the participants thought that where video shows are set up, there might be a problem of pupils spending too much time during the night at video shows. It was suggested that this is overcome by setting community rules on time to close the video show and also limits to the time pupils can be allowed to be present.

Sixth, the FGD was worried about community members facing accidents like electric shock when operating the solar equipment. There was agreement that this could be minimized by receiving proper training on how to operate solar equipment.

Finally, the issue of jealousy was specifically brought up. The FGD noted that the main potential issue was in the selection process for the entrepreneur who would be tasked with operating the local business and would like receive a relatively high income. Clear criteria and a transparent process which selects the most qualified person would reduce the chance of jealousy. General jealousy from the success of others was also cited but with no specific solution.

- ***Recommendations:*** While there is clearly excitement in the communities and potential benefits are expected by the community, the challenges which were cited are a major concern. The recommendations by the FGD participants should be pursued both because they are sensible mitigation approaches and because listening, taking the advice, and enlisting the help of the community may increase overall acceptance levels for the project. These recommendations were:
  - The business itself should publicize prices. The Project Partners can advise the community on the fairness of these prices.
  - Appropriate measures should be setup to avoid theft including: hiring security, locking up valuable equipment wherever possible or restricting access, and community policing.
  - Involve the community in the selection process for the entrepreneur as partners to help screen poor candidates that might otherwise be chosen. Recognise that the community has much more background then project partners on the history of the candidates.
  - Ensure that the selection process is clear and transparent. The criteria needs to be clearly understood to avoid jealousy.

The business which is created will create a situation where the operator (franchisee) likely benefits financially more than others. By design in the model, the incentive for the operator of business is high to ensure they remain in place. Risks of jealousy over the operator's success can perhaps be most feasibly reduced by the operator maintaining good relationships with customers and ensuring that many people in the village are benefiting from the business through enhanced access to energy.

4.14 Budgets of public facilities to pay for energy services

Provision energy services to public facilities[20] by development projects in the past have typically failed to account for the lifecycle costs required to maintain the system. In addition, budgets for rural public facilities do not often include an explicit energy expense as they lack either a grid connection or an off-grid system to provide power. If the equivalent spend on electricity usage at urban schools with grid access were provided for rural school, off-grid options may become much more affordable.

SOGERV's business model assumes that systems installed are financially supported by the public funding sources – in this case the Chikhwawa District Offices and scaled according to an affordable level. This

[20] 'Public Facilities' refers to health centres/posts and primary schools as used within this document.

follows the observation that many past failed projects have installed solar PV systems which are beyond the funding sources' ability to pay which have resulted in a 'graveyard' of failed projects.

Officials at the public facilities provided the following information on the current annual budgets. Format: (total budget / facility maintenance budget / specific budget for energy services).

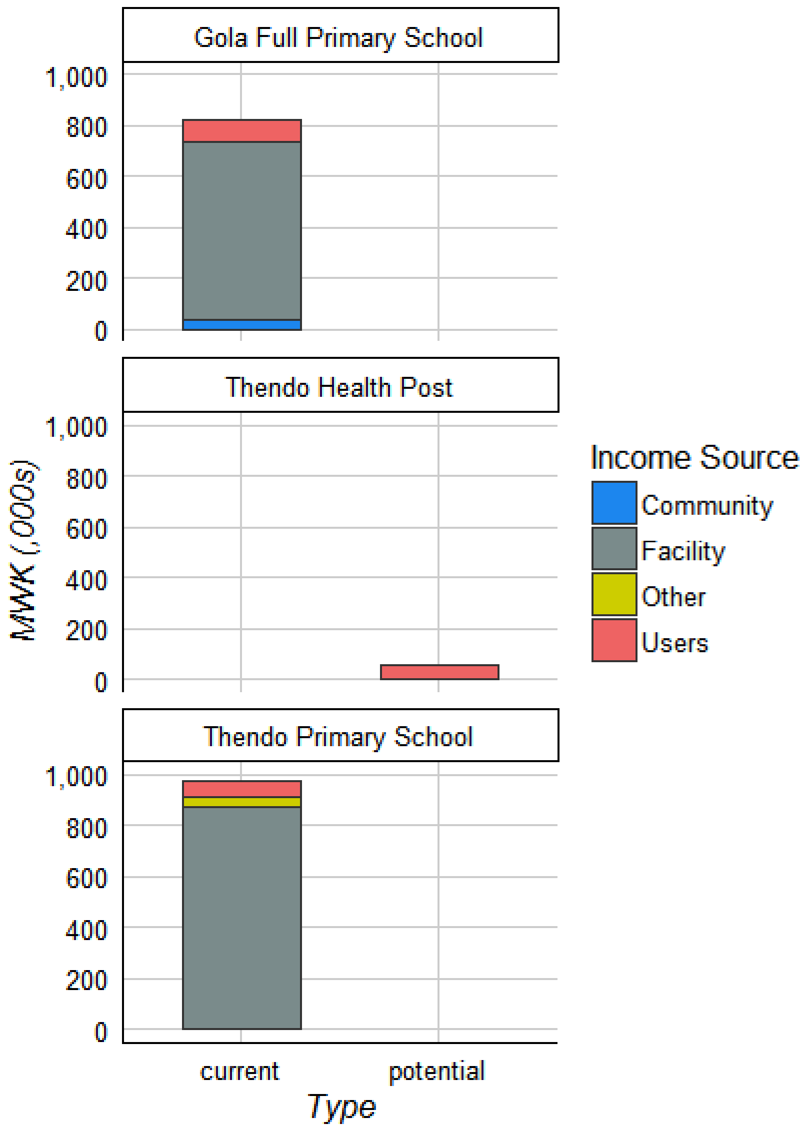
- Primary School Kandeu –800,000 / 250,000 / unknown
- Primary School Mandrade - 718,088 / 520,000 / 110,000
- Health Post at Kandeu - unknown/ unknown / unknown - no fixed budget
- Health Post at Mandrade - 2,500,000 / unknown / unknown - no fixed budget

Potential yearly funding for the Gola and Thendo facilities are shown as follows. In the second phase of the market assessment, the team changed approach and asked several key informants for each remaining location about current and potential sources of income for the systems at the public facilities.

- Gola Primary School
    - Community generated – 35,000 MWK
    - Facility generated – 700,000 MWK
    - User generated – 84,000 MWK
- Thendo Primary School
    - Facility generated – 870,000MWK
    - User generated – 66,000 MWK
    - Other sources – 41,000 MWK
- Thendo health Post
    - (Potential) User generated – 60,000 MWK

For phase 2, the primary schools had more identified sources than health facilities at Gola and Thendo, with facility generated funds cited as the largest source. In comparison, community and user generated income represented only 14% (119,000 MWK/yr) at the Gola primary school and 10% (107,000 MWK/yr) at the Thendo primary school. Respondents included teachers, head teachers, the health assistances, and community leaders.

Identified Income Sources



A separate business modeling activity was completed concurrent to the MA and technical design work, to determine the energy requirements, system sizing and indicative costing of systems expected to be highly technically sustainable over a 20 year+ lifespan.

In this work, the design standards for all systems were based on national and international design standards which specify a high level of reliability of service. The design team felt that these system will outperform, technically, the status quo for system installed typically in Malawi while minimizing costs as much possible.

General Assumptions of Design Approach

Assumption	Value

Days of autonomy (school systems)	3 days
Days of autonomy (health systems)	4 days
Average full sun hours per day	5.07

Days of autonomy refers to the number of days the systems could run without any power cut if there were no sun at all. We designed an extra day of autonomy for the health facilities given the critical nature of their use. We also assumed only 5 hours of full sun per day, which is the worst case scenario and occurs only in July – this is a relatively conservative estimate.

The table below describes the results of the sizing exercise for each system option and

System Option	Location	Energy Requirement Estimation	Required Panel Sizing	Required Battery System Sizing
School -Classroom Block	1 at each location (4 total)	Room Lights (18) Security Light (2) TV Use (1)	750W	612Ah
School -Staff Room	1 at each location (4 total)	Room Lights (4) Security Light (2) Phone Charging Laptop (1)	750W	612Ah
Health Facility (small Post)	Kandeu	Room Lights (4) Security Light (2) Phone Charging Refrigerator Microscope	750W	612Ah
Health Facility (small centre)	Mandrade, Gola*, Thendo*	Room Lights (8) Security Light (3) Phone Charging Refrigerator Microscope	1000W	816Ah

*assumed

The business model uses a "lifecycle" costing approach which finds out the costs involved with maintaining the systems over its entire life. Solar PV system can last over 20 years if maintained properly, though many in Malawi have failed after only 2 years! While SOGERV will be paying for the upfront capital costs of the equipment. It is responsibility of the business which owns and operates the systems therefore to save and pay for any ongoing costs for replacing equipment which fails.

Solar PV systems are complex and involve several expensive components that need to be cared for. Although it is rare for them to fail, over time all of these components will inevitably fail. Below are the expectations for life of the main components of solar PV system depending on whether they are well maintained or treated poorly:

Component Life Expectations

Equipment	Poor treatment/maintenance	Good treatment/maintenance
Solar Panels	10-15 years or less if damaged	25 years

Charge Controller	3-5 years	10+ years
Inverter	3-5 years	10+ years
Batteries	2-3 years	5-10 years

An example calculation has been shown below for the system design for a staff room at a primary school that can handle a laptop and phone charging in addition to lighting. All values are in thousands of MWK (so 1 = 1000MWK). The cost of replacement of parts is incorporated in each relevant year. A small maintenance cost (5%) is included per year. An administrative fee is additionally included which is equal to 25% of the average yearly costs and which is required to provide management over the system.

Initial Cost	-3,495			
Cost per Year				
1	**2**	**3**	**4**	**5**
-175	-178	-182	-185	-189
6	**7**	**8**	**9**	**10**
-470	-197	-201	-205	-209
11	**12**	**13**	**14**	**15**
-1,155	-217	-222	-226	-231
16	**17**	**18**	**19**	**20**
-572	-240	-245	-250	-2,196
Yearly Maintenance Fees	-175			
Average Yearly Cost	-387			
Average Yearly Cost with Administrative Fee	-456			

The expected costs for all of the systems, using this method, are shown in the table below. .

Required Financial Support for Different System options

System	**Location**	**Monthly Cost**	**Yearly Cost**	**Costs for all systems**
School -Classroom Block	K,M,T,G	38,000	456,000	1,824,000
School -Staff Room	K,M,T,G	38,000	456,000	1,824,000
Health Facility (small post)	K	38,000	456,000	456,000
Health Facility (small centre)	M,T*,G*	52,250	627,000	1,881,000
			total	5,985,000/year

*Assumed, KEY: K=Kandeu, M=Mandrade, T=Thendo, G=Gola

A monthly payment will be required by the District for each system installed.

> ***Recommendations:*** The required costs for the systems - totaling at around MKW 6m/year would likely require a large proportion of current budgets of the facilities, most likely beyond what can immediately be committed. Further financial support will be needed to support the installations.

SOGERV has identified a role in WASHTED to engage with the district on the options and financial obligations for installation of these systems. This consultation process is now fully informed and should proceed.

Ongoing financial support should be written into future district development plans which provided the mandate for paying for such services. Failure to do so will put additional pressure on the rest of the business (consumer- and business-energy supplies) to compensate for the lack of funding from public sources which may lead to sustainability challenges. SOGERV must be upfront with all stakeholders on this risk, its implications, and ensure set clear expectations are set. This includes reaching out to the District, the community, the business operators, personnel at the public facilities, and finally to the Scottish Government as the funding source.

4.15 Solar Resource

The solar resources assessment comes from two main sources. The primary source is a solar resource mapping modelling report commissioned by the ESMAP[21]. The assessment produces a comprehensive data set based on satellite and meteorological modelling, validated by ground measurements. The closest stations included are in Nsanje and Blantyre. With regard to the ESMAP report, weather values in Nsanje are considered to be the most similar to Chikwawa conditions.

Temperature conditions are used in the calculation of losses for solar photovoltaic based systems as they have impact on both panel output and lead-acid battery capacities. For the case of Nsanje, average yearlong temperature is 24.9°C, very similar to standard test condition usually 25°C. However, there is some variation over the year between 20°C in July to 29.5°C in November.

Figure: Monthly Averages for air-temperature at 2m at 7 sites (source: ESMAP report)

Month	Temperature [°C]																				
	Karonga			Mzuzu			Mzimba			Chitedze			Mangochi			Blantyre			Nsanje		
	Average	Min	Max	Average	Min	Max	Average	Min	Max	Average	Min	Max	Average	Min	Max	Average	Min	Max	Average	Min	Max
January	**24.5**	19.5	30.8	**20.5**	16.3	26.2	**19.3**	16.1	23.7	**20.6**	17.0	25.7	**23.9**	19.9	29.6	**23.1**	19.1	28.6	**27.1**	22.1	33.7
February	**24.2**	19.3	30.3	**19.9**	15.7	25.5	**18.9**	15.7	23.1	**20.1**	16.1	25.4	**23.2**	19.2	28.8	**22.2**	18.2	27.6	**26.0**	21.2	31.9
March	**23.5**	18.3	30.1	**19.2**	14.6	25.1	**18.8**	15.4	23.5	**19.9**	15.8	25.4	**22.8**	18.8	28.5	**21.7**	17.7	27.2	**25.3**	20.5	31.4
April	**21.8**	16.5	28.4	**17.4**	12.2	23.6	**17.6**	13.8	23.0	**18.6**	13.7	25.2	**21.3**	16.6	27.6	**20.0**	15.3	26.0	**23.5**	17.8	29.9
May	**20.1**	13.8	27.5	**15.5**	9.7	22.7	**16.3**	11.6	22.9	**17.2**	11.2	25.1	**19.9**	14.0	27.4	**18.4**	12.8	25.5	**21.8**	15.0	29.4
June	**18.2**	11.4	26.1	**13.6**	7.3	21.1	**14.6**	9.8	21.6	**15.6**	9.3	23.6	**18.5**	12.5	26.0	**17.0**	11.7	23.9	**20.3**	14.2	27.4
July	**17.7**	10.8	25.7	**13.2**	7.1	20.6	**14.3**	9.3	21.3	**15.3**	9.1	23.1	**18.5**	12.5	25.9	**16.6**	11.4	23.1	**20.0**	14.0	26.9
August	**19.5**	12.4	27.5	**15.0**	8.6	22.6	**16.4**	11.1	23.4	**17.6**	10.9	25.5	**20.8**	14.3	28.6	**19.2**	13.0	26.7	**22.8**	15.9	30.5
September	**22.0**	14.9	30.0	**17.7**	11.5	25.2	**19.0**	13.4	26.0	**20.5**	13.8	28.3	**24.1**	17.3	32.2	**22.8**	16.2	30.7	**26.5**	18.9	35.1
October	**24.1**	17.1	31.7	**19.8**	13.9	26.9	**20.7**	15.3	27.6	**22.4**	16.2	29.6	**25.9**	19.3	33.7	**24.7**	18.4	32.2	**28.1**	20.4	36.5
November	**25.2**	18.4	32.6	**21.1**	15.6	28.0	**21.7**	16.4	28.3	**23.3**	17.6	30.0	**26.7**	20.7	34.0	**25.9**	20.1	32.9	**29.5**	21.9	38.0
December	**24.9**	19.0	31.7	**20.8**	16.0	26.9	**20.4**	16.3	25.8	**21.8**	17.4	27.7	**25.1**	20.4	31.6	**24.2**	19.6	30.6	**28.3**	22.1	36.0
YEAR	**22.1**			**17.8**			**18.2**			**19.4**			**22.6**			**21.3**			**24.9**		

For flat-plate technologies, the relevant measure for irradiance is Global Tilted Irradiation (GTI) which assumes optimum tilt of PV modules. Optimum title is not the same throughout Malawi given its long, North to South orientation. The optimum tilt in Southern Malawi is 18° facing North.

---

[21] Suri, Marcel; Suriova, Nada; Cebecauer, Tomas; Skoczek, Artur; Betak, Juraj; Schnierer, Branislav. 2015. Solar resource mapping in Malawi : solar modeling report. Washington, D.C. : World Bank Group. http://documents.worldbank.org/curated/en/2015/07/24758967/solar-resource-mapping-malawi-solar-modeling-report

Figure: Global Tilted Irradiation at optimum angle – long-term averages at daily/yearly totals [Source: ESMAP]

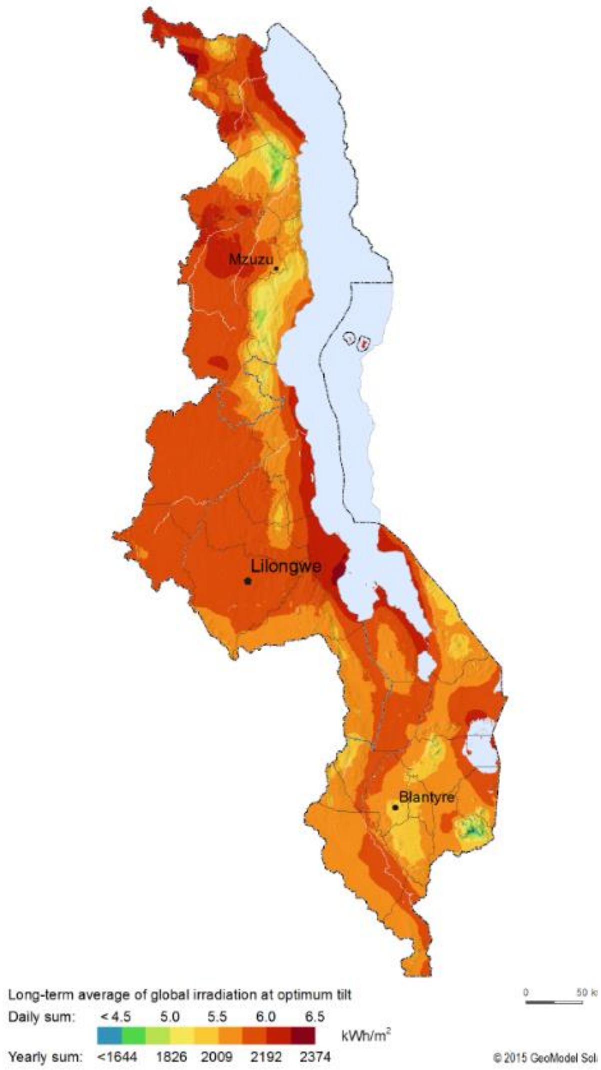
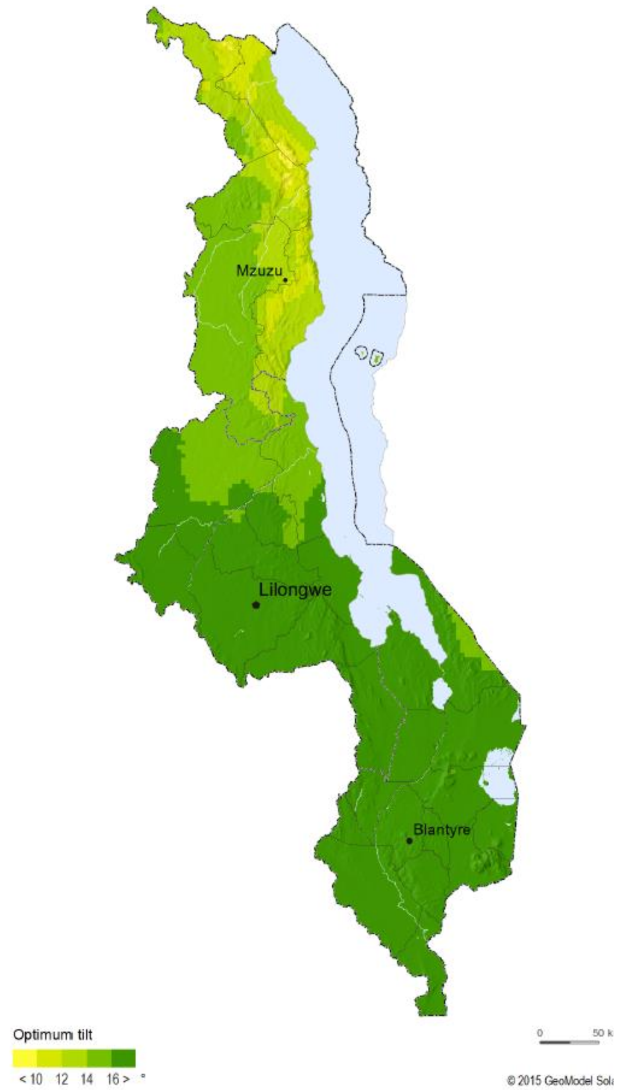


Figure: Optimum tilt of PV modules towards North to maximize yearly energy yield. [Source: ESMAP]



The solar resource throughout Malawi can be considered quite strong averaging between 5.6 – 6.2 kWh/m^2 of daily average GTI. GTI in Nsanje averages 5.8 kWh/m^2 per day with October the best performing month and July the worst performing (6.5 kWh/m^2 and 5.07 kWh/m^2 respectively)

Figure: Daily averages and average minima and maxima of Global Tilted Irradiation at 7 sites [Source: ESMAP]

Month	Global Tilted Irradiation [kWh/m^2]													
	Karonga		Mzuzu		Mzimba		Chitedze		Mangochi		Blantyre		Nsanje	
	Average	Min Max	Average	Min Max	Average	Min Max	Average	Min Max	Average	Min Max	Average	Min Max	Average	Min Max
January	**5.25**	4.25 5.96	**4.87**	4.29 5.26	**4.86**	4.42 5.27	**4.89**	4.27 5.67	**5.14**	4.49 5.85	**5.04**	4.46 5.61	**5.44**	4.49 6.34
February	**5.43**	4.45 6.21	**4.93**	4.19 5.64	**5.00**	4.42 5.73	**5.22**	4.07 6.43	**5.59**	4.22 6.86	**5.53**	4.05 6.52	**5.73**	3.95 6.75
March	**5.88**	5.00 6.45	**5.31**	4.33 5.89	**5.36**	4.29 6.19	**5.67**	4.93 6.61	**6.16**	5.30 7.38	**5.72**	5.08 6.81	**6.06**	4.90 6.59
April	**6.00**	5.44 6.67	**5.08**	4.25 5.61	**5.95**	5.38 6.50	**6.03**	5.09 6.66	**6.36**	5.27 7.03	**5.76**	4.65 6.42	**5.91**	5.14 6.60
May	**6.10**	5.69 6.59	**5.30**	4.36 6.17	**6.25**	5.05 6.78	**6.14**	4.74 6.88	**6.34**	5.13 6.87	**5.70**	4.23 6.31	**5.63**	4.95 6.18
June	**6.03**	5.54 6.35	**5.07**	4.48 5.89	**6.11**	5.65 6.60	**5.77**	4.86 6.40	**5.79**	5.15 6.20	**5.12**	4.35 5.62	**5.11**	4.46 5.79
July	**6.18**	5.59 6.61	**5.11**	4.42 6.07	**6.14**	5.55 6.81	**5.63**	4.50 6.48	**5.72**	5.12 6.28	**5.00**	4.01 5.91	**5.07**	4.31 5.94
August	**6.71**	6.18 7.12	**5.98**	4.96 6.81	**6.58**	5.83 7.31	**6.21**	5.08 6.88	**6.24**	5.37 6.92	**5.77**	4.87 6.33	**5.92**	5.24 6.36
September	**7.15**	6.60 7.39	**6.84**	6.00 7.41	**7.18**	6.73 7.56	**6.88**	6.30 7.36	**6.74**	6.08 7.29	**6.50**	5.69 7.02	**6.43**	5.69 6.74
October	**7.21**	6.76 7.53	**6.90**	6.08 7.52	**7.05**	6.26 7.43	**6.69**	5.96 7.34	**6.66**	6.09 7.23	**6.31**	5.57 7.00	**6.50**	5.56 7.05
November	**6.65**	5.29 7.31	**6.44**	4.71 7.41	**6.29**	4.69 7.31	**6.05**	4.68 7.00	**6.25**	4.90 6.81	**5.92**	4.84 6.32	**6.21**	5.25 6.62
December	**5.74**	4.94 6.55	**5.30**	4.47 6.30	**5.25**	4.53 6.10	**5.18**	4.19 5.96	**5.60**	4.51 6.21	**5.39**	4.48 6.00	**5.65**	5.18 6.23
YEAR	**6.20**	**6.04 6.42**	**5.60**	**5.24 5.92**	**6.01**	**5.81 6.28**	**5.87**	**5.48 6.21**	**6.05**	**5.56 6.40**	**5.65**	**5.24 6.00**	**5.80**	**5.47 6.10**

The ESMAP report provided useful reference points for solar PV system modeling. This estimates that typical system losses will vary between 17.6-23.3%. Given these loss estimates it is estimated that that average daily total PV electricity yield at Nsanje is 4.4 kWh/kWp with a performance ratio available of 75.8%.

Figure: Summary of yearly energy losses and related uncertainly in PV power simulation. [Source: ESMAP]

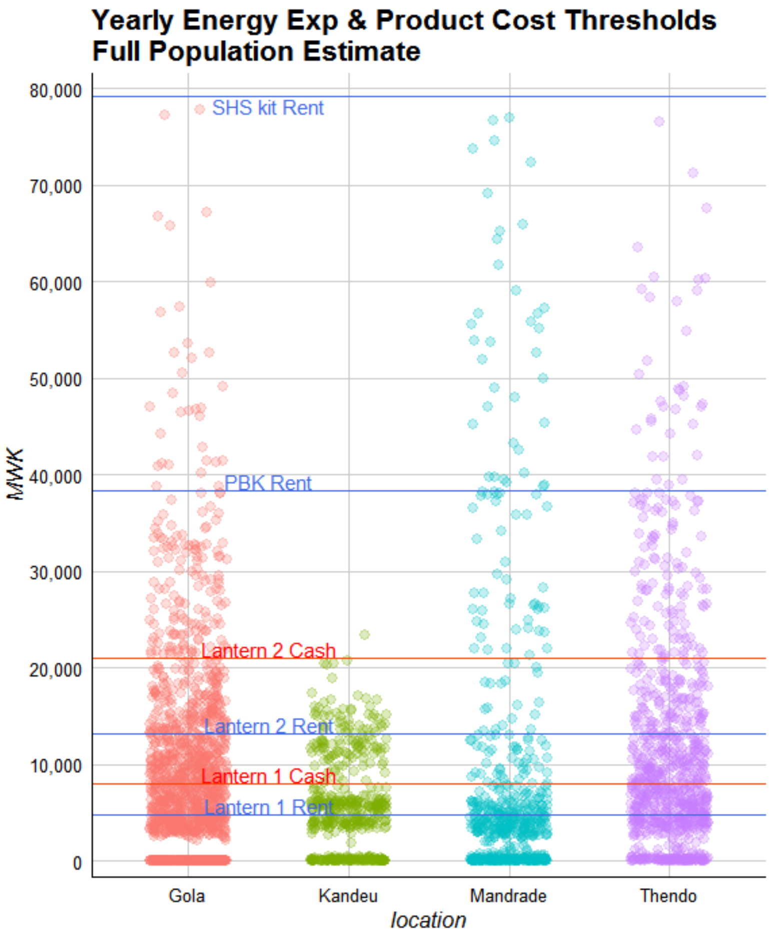
Simulation step	Losses	Uncertainty	Notes
	[%]	[± %]	
Global Tilted Irradiation (model estimate)	N/A	7.0	Annual Global Irradiation falling on the surface of PV modules
Polluted surface of modules (empirical estimate)	-3.0	1.5	Losses due to dirt, dust, soiling, and bird droppings
Module surface angular reflectivity (numerical model)	-2.5 to -2.9	1.0	Medium polluted surface of PV modules is considered
Module inter-row shading (model estimate)	-0.5	0.5	Partial shading of strings by modules from the preceding rows
Conversion in modules relative to STC (numerical model)	-7.0 to -13.0	3.5	Depends on the temperature and irradiance. NOCT of 45ºC is considered
Mismatch between modules (empirical estimate)	-0.5	0.5	Well-sorted modules and lower mismatch are considered.
Power tolerance (value from the data sheet)	0.0	0.0	Value given in the module technical data shee (modules with positive power tolerance)
DC cable (empirical estimate)	-2.0	1.5	This value can be calculated from the electrica design
Conversion in the inverter (value from the technical data sheet)	-2.0	0.5	Given by the Euro efficiency of the inverter, which is considered at 98.0%
Transformer and AC losses (empirical estimate)	-1.5	0.5	Standard transformer and AC connection is assumed
Availability	0.0	0.0	A theoretical value of 100% technical availability is considered
Range of cumulative losses and indicative uncertainty	-17.6 to -23.3	8.2	These values are indicative and do not consider a number of project specific features and performance degradation of a PV system over its lifetime

5 Conclusions

The SOGERV Market Assessment developed and tested new questionnaires for households and businesses to capture key data. Focus Group Discussion were held with a range of stakeholders in each village to verify the quantitative data and to explore issues which were difficult to capture in questionnaires. 314 household and 46 businesses were surveyed in total. This new data was supplemented with data from the SOGERV baseline and external sources to complete the analysis.

The target villages have very low incomes and equally low expenditure on energy. Interestingly, the link between energy expenditure and income was not consistent in each village; nor was the relationship statistically significant. Although modest, a market exists in both locations stemming from the willingness to pay by households, lack of competition, and stated interest in productive services. The entry cost for energy products and services is an important factor – at the critical threshold of around 6600 MWK per month of spend the number of customers in both villages reduces to zero. Thus, financing, which is in short supply and currently comes at a high premium (current averaging around 240% annual interest rates), must be packaged within any product/service offerings.

In Mandrade, the population is estimated at 3,037 in 604 households corresponding to an average household size of 5.03. In Kandeu, there are three nearby clusters of structures with a total population in this area is 2,143 in 473 households. This corresponds to an average household size of 4.53. Gola had an estimated 1334 households (6043 people) and Thendo had an estimated 841 households (3810 people).



The willingness to pay for specific objects ranging from solar lanterns to a mini-grid connection was explored. Respondents consistently undervalued the objects both in the willingness to pay to rent access the object or to buy it outright. The proliferation of low quality products and the 'craftiness' of vendors have led to skepticism from the consumers on the products that are currently available.

A new business established in these areas will need to overcome these negative legacies through good business fundamentals: fulfilling relationships with customers, demonstrated value, and sufficient training/marketing for customers. Inclusion of financial arrangements, through rental or leasing is needed to ensure that prices are sufficiently low for these consumers for to get started. Current skill levels are low levels for potential local operators who could be involved in the project. It is likely that a significant training effort will be needed to support the skill shortage. In addition, a local supply chain for products and replacement parts will need to be established at all locations.

As shown in the figure, using current energy expenses households, even with the lowest pricing methodology and cheapest product, some households will not be able to afford any product. However, at all locations appear to be households and businesses that are interested and able to purchase renewables based products to replace their current energy sources.

The Market Assessment revealed potential challenges the new businesses would face and equally some solutions. This included providing fair and published prices and taking steps to ensure theft does not become a problem. Risks of jealousy can be minimized by ensuring a transparent selection process for the local operator which enlists the support of the community. Finally, appropriate measures should be setup to avoid theft including: hiring security, locking up valuable equipment wherever possible or restricting access, and community policing.

Interest is high for the new energy supply business and the community is expecting general development benefits, which should be mostly achievable.

Figure – Business Opinion on likely profitability of various Productive Uses of Energy

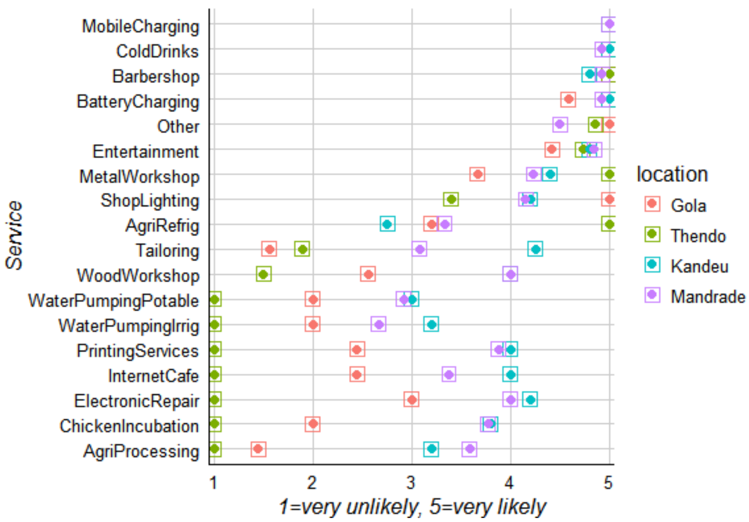
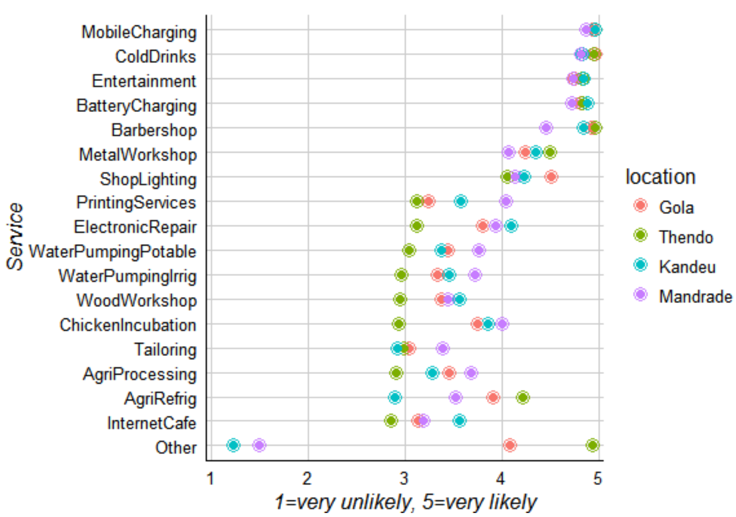


Figure – Household Opinion willingness to pay for various Productive Uses of Energy



Through the availability of well-priced products, households will benefit from basic lighting and mobile phone charging. Small businesses focusing on entertainment, mobile phone charging, and the sale of cold drinks are anticipated. Lighting at public facilities will improve the ability of teachers and health assistants to do their jobs more effectively.

In order for it to be sustainable, such provision needs to be economically sensible – or in other words, these source need to be able and willing to pay for the products and services provided. Household demand for energy seems the most reliable with the data gathered assuming the entry price points low enough. Although businesses expressed their interest in products and setting up their own productive businesses, current energy spend is extremely low so they may need convincing of the value of energy access to the productivity of their business. The market assessment has revealed a relative agreement for households and business on the most desirable businesses which make productive use of energy.

The top seven include: **mobile phone charging, selling cold drinks, barbershop, charging batteries, metal workshops, providing shop lighting,** and **agricultural refrigeration**. This result provides a basis for further investigating the economic prospects of these activities and how best the village level energy provider can setup business-to-business energy services. It is recommended that business plans for these activities are developed alongside any technical modeling for electric systems.

Finally, the budgets for public facilities to pay for electric access appear to be limited, poorly defined, and may be subject to further negotiation involving district and community sources. Without a regular funding source to underpin the installed system, either the systems capability or expectations for sustainability will need to be scaled back. A subsidy approach may be possible at the village level, where productive activities priced on a commercial basis provide a subsidy for public facility funding, though the need to hike prices on the non-subsidized activities may push the poorer customers out of the market.

Specific ***Recommendations*** for the SOGERV Business made in the Market Assessment are:

- The **highest scoring productive uses** were mobile phone charging, battery charging, entertainment, barbershop, metal shop and shop lighting. The high scoring uses need to be passed on to the technical design team for consideration for standalone solar PV system design. Furthermore, the development of business plans for each of these activities is needed to ensure there is an economic basis for the investment.

- Using current business energy expenditures as the measure, they will not be able to pay for even the most basic products. However, the agreement between consumers and businesses in the productive services warrants continued exploration in providing **access to electricity for businesses as income source**. Furthermore, when asked about specific products, business appeared more willing to pay to gain access. This argument assumes that there is in fact a latent demand for electricity-enabled business products and services, but this has not been confirmed through the study.

- The low **Willingness to Pay (WTP)** for the available products would imply that a rental or leasing payment options were pursued. Given the low familiarity with these arrangements, it necessitates the business model include training/marketing around how the financing arrangements are established.

- With the low levels of debt, ownership of bank accounts, and high interest rates, it is clear that **financial capacity in the villages are extremely limited**. The intended energy businesses established by SOGERV will therefore need to be able to manage a financing arrangement in order to make products/services affordable by the local population.

- For the business model design, **product selection should err towards smaller systems** which are less costly. Limited cash sales will be possible with the current availability of finance, to take on debt, in the villages. As a result, in order to provide access to more functional products, a financing arrangement will need to be offered by the installed business which allows either for a rent-to-own or fee-for-service. This will lower the income entry point for the products.

- **Available finance is extremely low and interest rates are eye-wateringly high**. According to the current debt-owners, the yearly interest rate well over 240% (in Gola it is over 500%), so any rate less than this could be considered acceptable. Average debt size was around 34,000 MWK. A more reasonable rate could be offered at the current Reserve Bank of Malawi rate set at 27%.

- For the current market, the cap on the yearly rental price appears to be very near the rental price threshold for solar home system, or 80,000MWK. **An "upper-income" segment could be set around 40,000 MWK/yr** rental with additional thresholds for products set at lower levels.

- Current **yearly energy expenditure** for lighting is assumed to represent the main market for the any new businesses as the current energy sources are supplanted with new renewables products. In Kandeu this is estimated to be 3.04 million MWK/year. In Mandrade, Gola and Thendo, yearly energy expenditure to 6.84m, 14.47m, 10.06m MWK/year, respectively.

- With the low level of competition, lack of existing renewable energy products, and WTP, products targeted at the right entry point should be in high demand. Emphasis on marketing of products (in some cases consumer training), and satisfying consumer relations will overcome current barriers and improve potential of the business to capture more of this market.

- The **required costs for institutional based PV systems** – totaling at around 6 million MWK/ year (see table), would likely require a large proportion of current budgets of the facilities, and are **most likely beyond what can immediately be committed by public facilities**. Further financial support will be needed to support the installations. SOGERV has identified a role in WASHTED to engage with the district on the options and financial obligations for installation of these systems. Failure of the district to provide basic funding may require system scale-back, or identification of a substitute income source, to remain sustainable.

System	Location	Monthly Cost	Yearly Cost	Costs for all systems
School -Classroom Block	K,M,T,G	38,000	456,000	1,824,000
School -Staff Room	K,M,T,G	38,000	456,000	1,824,000
Health Facility (small post)	K	38,000	456,000	456,000
Health Facility (small centre)	M,T*,G*	52,250	627,000	1,881,000
			total	5,985,000/year

- Ongoing financial support should be written into future district development plans which provided the mandate for paying for such services. Failure to do so will put additional pressure on the rest of the business (consumer- and business-energy supplies) to compensate for the lack of funding from public sources which may lead to sustainability challenges.

- As it appears that skills levels are minimal, personnel at any business will need significant technical training to competently manage the installed power systems**. A dedicated training provision is needed** and would ideally cover all the major aspects of solar PV systems installation, operation, maintenance, trouble shooting. If realistic levels of training cannot be provided, technical system design should be limited to a level appropriate to the operator. Furthermore, a district level training provision should be sought to reinforce a learning culture for when the project concludes.

- The lack of current stocks of renewables equipment is not unexpected, as a rural market no suppliers have set up shop in these locations. **Businesses setup up in these locations will require a supply chain setup for critical components**. Suppliers will need to be sought out in Chikhwawa Boma or Blantyre if necessary for the main components (Panels, batteries, charge controllers, inverters). In addition, a sufficiently sized inventory should be kept for consumer products sold in conjunction with the business and to minimize the impact of replacement on the consumer service provision.

- **Lack of consumer knowledge and the legacy of poor products** in the market translates to a likely consumer wariness to buy new renewable products, despite their quality. An energy supply business will need to combine consumer training with sales efforts so that consumers are informed. The onus is on the business to prove that its products and services are high quality. Measures such as providing a warranty and ensuring reliable service levels will reassure customers. SOGERV should provide general, community level training on renewable energy appreciate in order to dispel any misconceptions on solar products, use high quality Lighting Global certified products and ensure the economics for the household are clearly explained so they can recognize the savings and value they get from products.

6 Appendices

- SOGERV Market Assessment Household Questionnaire (English)
- SOGERV Market Assessment Household Questionnaire (Chichewa)
- SOGERV Market Assessment Business Questionnaire (English)
- SOGERV Market Assessment Institutional Questionnaire (English)
- SOGERV Market Assessment Visual Aid for Questionnaire
- SOGERV Market Assessment Focus Group Discussion Instructions & Questions
- Data, Kobocollect master forms, and R-code available upon request